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VOL. 101

"EVERY MAN IS A VALUABLE MEMBER OF SOCIETY WHO, BY HIS OBSERVATIONS, RESEARCHES, AND EXPERIMENTS, PROCURES KNOWLEDGE FOR MEN"—SMITHSON

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C. G. Abbot,
Secretary of the Smithsonian Institution.

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AN IMPORTANT WEATHER ELEMENT HITHERTO GENERALLY DISREGARDED

BY
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I wish to present evidence that, though small in percentage, the variation of the sun's output of radiation is an effective weather element.

THE VARIATION OF THE SUN

In other papers I have described the means used since 1902 by Smithsonian observers to measure the energy contained in solar radiation, to estimate the losses which the solar beam suffers in traversing the atmosphere, and to evaluate the "solar constant of radiation." The solar constant may be defined as the average intensity of solar radiation in free space at mean distance of the earth from the sun. Expressed in heat units its value is about 1.94 calories per square centimeter per minute.

By many thousands of determinations, Smithsonian observers have found that the solar constant changes from day to day and from month to month around its mean value. The extreme range of these excursions thus far observed is $5\frac{1}{2}$ percent. Monthly mean values since 1920 have an extreme range from 1.91 to 1.96 calories or $2\frac{1}{2}$ percent. Superposed on these fluctuations of monthly means are departures of a few days in length dependent to a great extent on the rotation of the sun. These short-interval changes, superposed on the changes indicated by monthly mean values, widen the extreme limits of solar variation to those given above as $5\frac{1}{2}$ percent.

The Smithsonian Institution operates several desert mountain solar-observing stations. Two of these, long occupied, are Table Mountain, Calif. (prior to 1926 at Harqua Hala, Ariz.), and Montezuma, Chile. These stations are at elevations of 7,500 and 9,000 feet, respectively. About 80 percent of all the days of the year are nearly cloudless at these stations, though not always of first-rate quality for solar-constant work.

Figure 1 gives the march of the monthly means of the solar constants from (A) combined results of Harqua Hala and Table Mountain, and (B) from Montezuma. The curves cover the years 1920 to 1939.

The preparation of figure 1 was delayed in order to use later results of the revision of solar-constant values. Individual daily values, however, will still be under consideration and revision for several more months, so that even the curves shown in figure 1 are not final. Yet they are improved and differing somewhat from those shown in figure 8, which was prepared at an earlier stage of the revision.

Figure 1 employs revised Montezuma data, beginning with September 1923, and revised Table Mountain data, beginning with December 1925. Montezuma data from August 1920 to August 1923

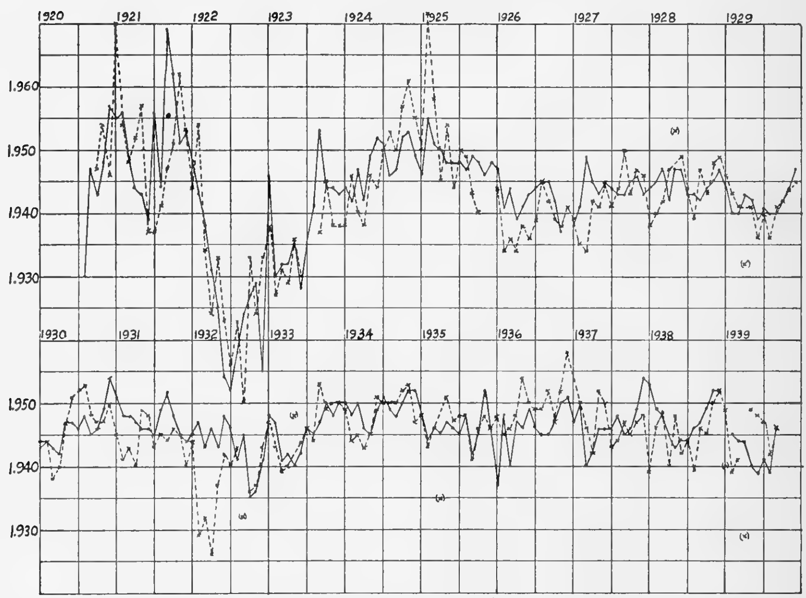

FIG. 1.—Solar constant monthly means. Dotted curve North America, full curve South America.

are taken from table 31 of volume 5 of the Annals of the Astrophysical Observatory.

The Harqua Hala data employed in figure 1 are not fully satisfactory. They are derived as follows. Table 29-a of volume 5 of the Annals gives daily "long-method" Harqua Hala solar constants, from which monthly mean values were computed. The resulting monthly means, when compared with simultaneous Montezuma "short-method" data given in table 31 of volume 5 of the Annals, indicate an average deficiency of 0.004 calorie in scale for the Harqua Hala "long-method" data. Referring to table 1 of my paper "Provisional Solar Constant

Values,"[1] the monthly mean "short-method" Harqua Hala values were recomputed from October 1920 to November 1924. Daily values marked "U" were omitted from the means. Upon comparing these monthly "short-method" means with the simultaneous monthly "long-method" means from table 29-a of volume 5 of the Annals, there seemed to be no marked difference in scale up to December 1922, but thereafter there was found to be an average deficiency in the "short-method" monthly means of 0.008 calorie up to January 1924, and of 0.023 calorie, February 1924 to October 1925. It is not possible now, without a very tedious and thorough examination of the original records to detect the cause of this change of scale, but an allowance was made, as follows.

The "short-method" daily values are much more numerous than the "long-method" ones, and are also regarded as less subject to accidental errors. Hence, I preferred to use them for figure 1. Taking account of the discrepancies of scale just mentioned, the Harqua Hala results plotted in figure 1 are based on the "short-method" daily values, but are reduced to the Montezuma scale by adding 0.004 calorie for the interval October 1920 to December 1922, and 0.004+0.008=0.012 calorie from January 1923 to January 1924. From February 1924 to October 1925 there was added 0.004+0.023=0.027 calorie.

The interval December 1924 to December 1925, at which latter month the revised Table Mountain values begin, is not covered in "Provisional Solar Constant Values."[1] This interval has been nearly closed by using hitherto unpublished Harqua Hala "short-method" monthly means. Comparison with "long methods" determines their scale corrections in the same manner explained above, and I increased these "short-method" monthly means, as stated above, by 0.027 calorie. As the Harqua Hala data are obviously less eligible, I give the average monthly mean differences from Montezuma values for the interval 1920 to 1925, inclusive, separately from those for 1926 to 1940. But all are used in combination in the grand mean for the interval 1920 to 1940.

Mean (Montezuma—Harqua Hala) 1920 to 1925	$= \pm 0.32$	percent
Mean (Montezuma—Table Mt.) 1926 to 1940	$= \pm 0.20$	"
Grand mean, 1920 to 1940	$= \pm 0.24$	"

Notwithstanding differences of 1,500 feet in altitude, 4,600 miles in latitude, summer conditions at the one station simultaneous with winter conditions at the other, 34° of north latitude against 22° of

[1] Smithsonian Misc. Coll., vol. 77, No. 3, 1925.

south latitude, these independently derived monthly means, which rest on determinations of approximately 5,000 separate days at each station, agree to within an average monthly difference of 0.24 percent. Fluctuations are shown of $2\frac{1}{2}$ percent in the solar constant which are common to both stations.

As computed from the average monthly differences, the probable error of a monthly mean value derived from the work of two stations is $\frac{0.84 \times 0.24}{\sqrt{2}} = 0.14$ percent. Thus the range of variation found is 18 times the probable error of the determination. In many cases the two stations unite to show continued trends of increasing or of decreasing solar-constant values during many months. In such cases, successive values support each other, so that the probability with which such trends may be ascribed to observational error is further reduced. These facts support the validity of solar variation.

I conceive, however, that evidences of the reality of solar variation, stronger even than this agreement between results of high accuracy from two far-separated stations, are to be found in correlations of these results with other phenomena, both solar and terrestrial. I shall discuss these below.

But before presenting the most striking of these correlations I will refer to many supporting evidences of solar variability heretofore published. Though these evidences individually may not all be weighty, yet taken altogether they are highly convincing, on the principle of the well-known fable of the bundle of fagots. I present them in figure 2 and give appropriate references to the literature, in what follows, covering these and other cases of similar bearing.

Figure 2 has reference letters, A, B, C, D, E, F, G, for convenience in citing evidence of different kinds.

A, B. SOLAR CONSTANT AND SOLAR CONTRAST

Graphs A and B relate to the contrast of brightness along the radius of the solar disk. We were accustomed at Mount Wilson to allow a large solar image to drift centrally across the slit of the spectrobolometer. In this way on each day of observation of the solar constant, we recorded the relative brightness of the sun's disk along its E-W diameter for a number of wave-length regions of the spectrum. For each chosen wave length, results of many days in the year 1913 gave the average march of brightness from center to limb of the sun's disk. The observed march on each individual day was then compared with this average. In figure 2 we see that on September 22, 1913, a day of high solar-constant value, the contrast of brightness, limb to center, was greater than normal, while on October 20, a day of low

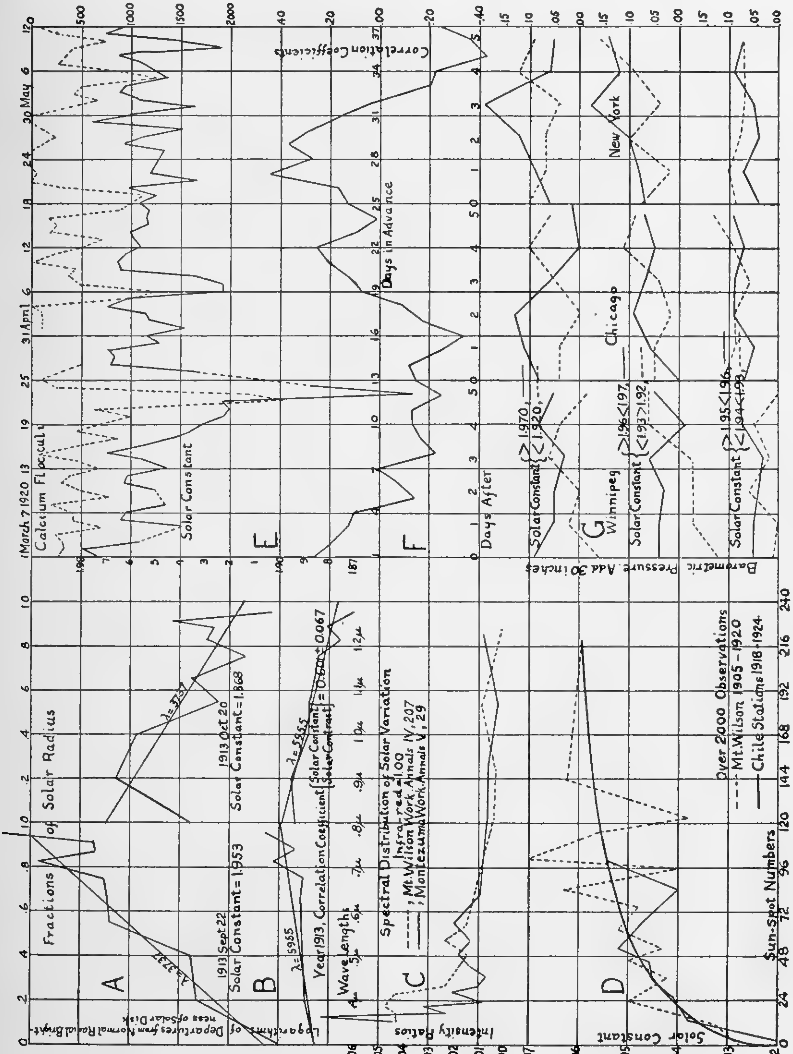

FIG. 2.—Various evidences of solar variation and its effects.

solar-constant value, the contrast was less than normal. The effect was far greater at wave length 3737 than at wave length 5955. This is as was to be expected, whether we regard the change of the solar constant as having been caused by change of the effective temperature of the sun's radiating layers, or by a change in the absorptive qualities of the sun's outer layers. Either change should affect shorter wave lengths most. This observation naturally leads us to graph C. But first let it be pointed out that from all wave lengths and all days of observation in the year 1913 there resulted a correlation coefficient of 0.601 ± 0.067 between solar-constant and solar-contrast changes. (See Annals, vol. 2, pp. 214-217, 1908; vol. 3, pp. 153-165, 1913; vol. 4, pp. 183, 184, 217-257, 1922; also Smithsonian Misc. Coll., vol. 78, No. 5, 1926.)

C. SPECTRAL DISTRIBUTION OF SOLAR-CONSTANT CHANGES

As foreshadowed by a comparison of graphs A and B, we are to expect that with increased solar-constant values the shorter wave lengths of the spectrum will show most increase. Graph C gives comparisons of this kind culled from results of Mount Wilson and early Montezuma work. Although the day-to-day solar-constant changes that figure in the comparison average little more than 0.5 percent, and though accidental errors make the graphs rather rough, both stations yield the same general indication, namely, that solar-constant increase is almost wholly confined to the visible and ultraviolet spectrum, and may be 10 or more times as great in percentage for wave lengths less than 3500 as for the total radiation. An unpublished investigation recently made with the latest revised Montezuma results confirms this conclusion. (See also Annals, vol. 2, pp. 105, 106, 1908; vol. 3, pp. 131-133, 1913; vol. 4, pp. 204-207, 1922; vol. 5, p. 29, 1932.)

D. SUNSPOTS AND THE SOLAR CONSTANT

The graph correlates the sunspot numbers of Wolf and his successors with over 2,000 observations of the solar constant of radiation made at Mount Wilson and in Chile between the years 1905 and 1924. The tendency is toward the conclusion that higher sunspot numbers are associated with higher solar-constant values. But, as graph E clearly indicates, on March 23, 1920, the central passage of an enormous sunspot acted strongly to diminish the solar constant. (These contrary tendencies are discussed by A. Ångström, Astrophys. Journ., vol. 55, pp. 24-29, 1922.)

E. OTHER SOLAR-SURFACE PHENOMENA AND THE SOLAR CONSTANT

In this graph we compare the solar-constant values of successive days, March 1 to May 11, 1920, observed at Calama, Chile, with the areas of calcium flocculi within 15° of the central meridian of the solar disk as measured at the observatory of Ebro in Spain. The dates given are for the solar-constant values. The dates of the calcium flocculi are displaced forward by one day in order to make best agreement. (See also Smithsonian Misc. Coll., vol. 77, No. 5, p. 22, fig. 14, and p. 23, fig. 16, 1925; vol. 77, No. 6, pp. 42-54 and 59-63, 1925; also Proc. Nat. Acad. Sci., vol. 26, No. 6, pp. 406-411, 1940).

F. THE SOLAR-ROTATION PERIOD AND THE SOLAR CONSTANT

This graph shows the march of correlation coefficients computed between the zero day and the days 1-37 thereafter, for all solar-constant values observed at Mount Wilson in the year 1915. The solar-rotation period is very plainly associated with a range of correlation coefficients from −0.40 to +0.40, or 0.80 altogether. (See Smithsonian Misc. Coll., vol. 69, No. 6, 1918, where the same phenomenon appears in the years 1910 and 1916, though less strongly marked; see also Smithsonian Misc. Coll., vol. 71, No. 3, p. 21, fig. 5, and pp. 41, 42, 43, 1920.)

G. ATMOSPHERIC PRESSURE AND THE SOLAR CONSTANT

This graph shows for three meteorological stations that the barometric pressure follows opposite courses after high and low solar-constant values, respectively. At Winnipeg the greatest opposition occurs on the zero day, at Chicago on the second, and at New York on the third day after the solar-constant influence. It is confirmatory of the value of this evidence that the greatest oppositions of pressure effects are found attending the widest departures of the solar constant, and that the oppositions of pressure effects consistently diminish as the solar-constant departures become less. (See also Smithsonian Misc. Coll., vol. 89, No. 15, pp. 13-35, 1934; also Bull. Amer. Meteorol. Soc., vol. 21, No. 6, p. 257, et. seq., 1940. See also figs. 1, 2, 11, 12, 16 of Smithsonian Misc. Coll., vol. 77, No. 5, 1925.)

A summary of many evidences of solar variation is given by H. H. Clayton (Smithsonian Misc. Coll., vol. 78, No. 4, pp. 50-62, 1926.)

A physicist to whom I showed figure 2 informed me that he considered graph F, which connects solar-constant variation with the sun's rotation period, to be the most convincing of all evidences of solar variation. Feeling that others may have the same view, I have obtained new evidence of this kind as given in figure 3. The curve F of figure 2 derives from Mount Wilson observations of 1915. In figure 3 I employ the revised solar-constant data, as yet unpublished.

They are derived by combining results of daily observations at both Montezuma and Table Mountain, in the years 1929, 1930, 1931 as

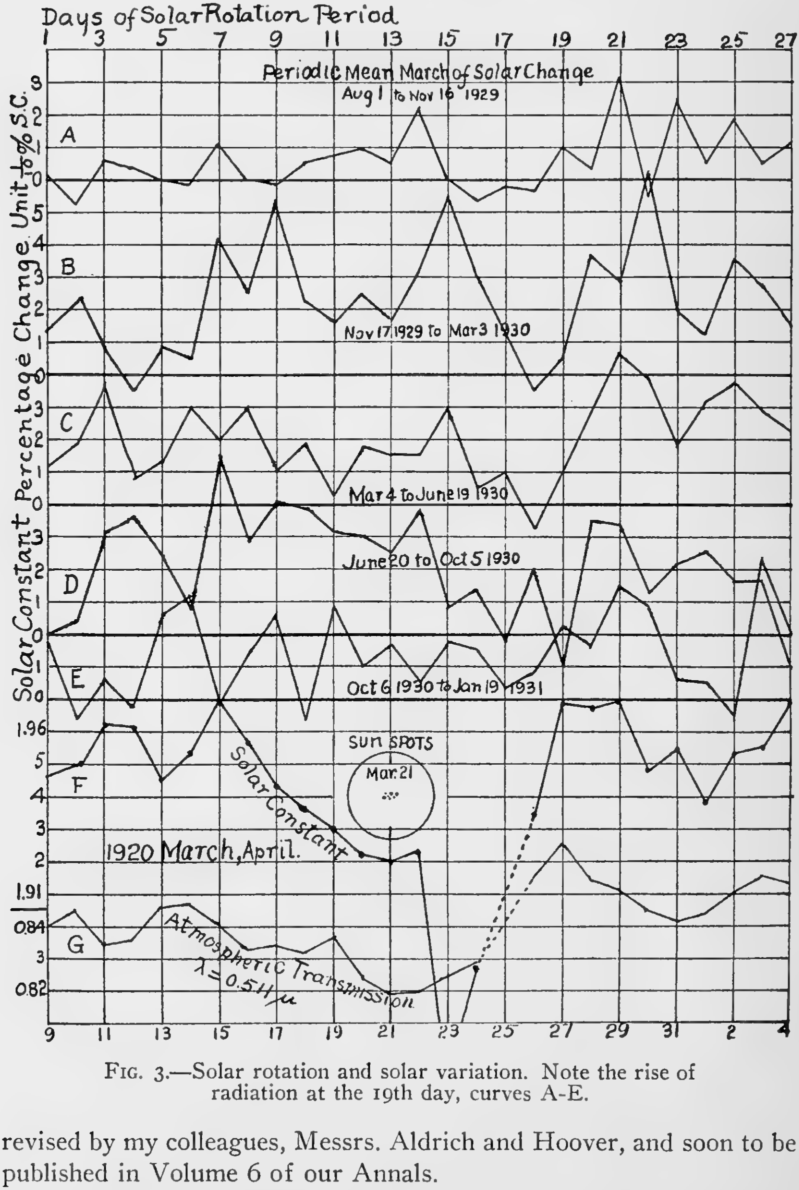

FIG. 3.—Solar rotation and solar variation. Note the rise of radiation at the 19th day, curves A-E.

revised by my colleagues, Messrs. Aldrich and Hoover, and soon to be published in Volume 6 of our Annals.

The data used to obtain figure 3 also yield by the method of correlation coefficients the fact that the solar constant has a 27-day periodicity of variation. The correlation coefficient between day 1 and day 27 from November 17, 1929, to October 5, 1930, is 45.5 ± 7.5 percent. By plotting the marches of means, each of four consecutive periods of 27 days, as in figure 3, they give the amplitudes of variation. The maximum amplitude at this time was about 0.5 percent.

My friend, the physicist, asked me to interpret for him the physical explanation of this 27-day period in solar variation. I replied that I conceive there is an emanation from the sun, especially active in sunspot regions, and emitted approximately normally to the solar surface. This emanation produces either scattering or absorbing, or both, for solar rays. Its columns are shot outward from the sun for hundreds of millions of miles, and take roughly conical shapes, with vertices at the sun's surface. As the sun rotates, these columns sweep through space, and when issuing from highly active regions of emission central to the solar disk, as occurred about March 22, 1920, the columns reach the earth and the solar constant is *diminished* by several percent.

The atmospheric transmission at such times is also materially reduced. The curves F and G of figure 3 show the position of the immense sunspots which prevailed on March 21, 1920, the depression of the solar constant on that day, and the simultaneous decrease of atmospheric transmission for homogeneous spectral rays at that time. The reader will, of course, understand that if the apparent decrease of atmospheric transmission were spurious, the effect of such an error would have been to *raise,* not *lower,* the solar-constant value computed.

The graphs in figure 3 should be compared with graph E of figure 2, that the reader may appreciate how frequently phenomena observed photographically near the center of the sun's disk are attended almost simultaneously by *depressions* of the solar constant. The sun's rotation brings these occurrences along every few days, and is the most prolific and readily understood cause of the fluctuation of the solar constant. The periodic long-range solar changes, which we shall describe further in what follows, are by no means so easy to understand. They seem to present features which are contradictory to expectation. These unexpected and contradictory phenomena will be discussed in the forthcoming Volume 6 of our Annals.

Solar rotation may also bring *increases* of solar radiation of 27-day periodicity, as shown beginning at the 18th day in curves A to E of figure 3. These increases occur (a) when the sun's rotation brings over the limb a sunspot group previously invisible, or (b) when new sunspots form or increase in size on the visible solar disk. Mount Wilson Observatory photographs, kindly loaned me by Dr. W. S. Adams, show that one or more of these phenomena occurred after the 18th day of each of the rotation periods dealt with in curves A to E of figure 3. Shorter lived cases also occur. See days 9, 15, B.

PERIODS IN SOLAR VARIATION

In order to introduce other solar and meteorological correlations above referred to, I now remind the reader that I published several years ago my discovery of a number of regular periods in the observed solar variation.[2] Several of these periods have been confirmed to within the error of determination by T. E. Sterne,[3] using other methods than mine.

I called attention, in my paper just cited, to the fact that the periods in solar variation, as I there determined them, had approximately a least common multiple of 23 years. This is approximately two sunspot periods of 11+ years. I mentioned also that the sunspot numbers themselves indicate a master cycle of two sunspot periods. I now give further evidence thereon, derived from summations I have made of monthly sunspot numbers published recently by W. Brunner, of the Observatory of Zurich.[4]

Beginning with the sunspot minimum in the year 1810, the comparative intensities of the 12 succeeding 11-year sunspot periods, as measured by the areas included under sunspot-number curves, are as follows. The 12th period being still incomplete, its area as given below is too small. The areas are given in arbitrary units.

Number of period.....	1	3	5	7	9	11	Total areas
Area	2354	6501	5451	3804	3739	4118	25967

Number of period.....	2	4	6	8	10	12	Total areas
Area	3879	6998	6222	4651	4412	5068	31239

Each odd-numbered area is smaller than the next succeeding even-numbered area, and the totals representing the relative average intensities of odd- and even-numbered sunspot periods from 1810 to 1940 are approximately as 5 to 6. This shows that for the last 130 years there has been a cycle in sunspot intensities comprising two 11-year periods. The average length of these periods since 1810 is 11.3 years.

The second correlation above referred to relates to G. E. Hale's observations of magnetism in sunspots. Hale found that sunspots prevailingly appear in pairs, of which the two members are of opposite magnetic polarity. During each 11-year sunspot period polarities per-

[2] Smithsonian Misc. Coll., vol. 94, No. 10, 1935.

[3] Proc. Nat. Acad. Sci., vol. 25, No. 11, 1939, and vol. 26, No. 6, 1940.

[4] See Terrestrial Magnetism and Atmospheric Electricity, September 1939.

sist unchanged with reference to advancing and following positions in solar rotation. But the polarities reverse at the beginning of each successive 11-year period. Hence, the double sunspot period of approximately 271 months is also the complete cycle in sunspot magnetism.

Various weather phenomena are also correlated with this complete sunspot cycle. Numerous meteorologists have noted a 23-year period in weather phenomena.[5] I give in figure 4 an example of 23-year periodicity in tree-ring widths. These curves I have computed by combining results from five localities in Southern California and Nevada including about 40 trees in all. The results are from data published by A. E. Douglass. I reproduce here also in figure 5 my illustration given as figure 33 in my paper "Solar Radiation and Weather Studies," already cited.

According to my former Smithsonian researches, the well-verified solar cycle of about 23 years which is accompanied by terrestrial effects, is the approximate least common multiple of 12 regular periodic variations of solar radiation.

In his first paper on these periodicities, Dr. Sterne found high probabilities in favor of my periods of $9\frac{3}{4}$, $11\frac{1}{4}$, 21, 25, $39\frac{1}{2}$, 46, and 68 months. The data were insufficient to enable him to test periods of 92 and 276 months. He found little evidence favorable to my periods of 7, 8, or 34 months. I am disposed to agree with him as to the elimination of periods of 7 and 34 months, but shall submit further evidence below favorable to a period of about 8 months.

However, the interval of 20 years, during which high-grade solar-constant observations have been carried on, is too short to fix accurately the lengths of the solar periods, or to indicate whether they continue indefinitely without shifting of phases, or changing of amplitudes. I desired to use long meteorological records to throw light on the first two of these interesting questions, but was at first balked, as meteorologists have frequently been, by changes of phase in the terrestrial periodicities which are supposedly associated with those in solar radiation.

CAUSE OF SOME PHASE CHANGES IN TERRESTRIAL PERIODS

It occurred to me that if, as is indicated by the 20-year analysis of solar variation which I shall present below, the solar periods follow on without changes of phase, then such a period as 8 months, if it has a maximum in January 1900, must have others in September 1900

[5] See Wild, Die Temperatur Verhältnisse des Russische Reiches, p. 279, 1881; also Quart. Journ. Roy. Meteorol. Soc., vol. 62, p. 481, 1936; also Douglass, Climatic cycles and tree growth, vol. 2, pp. 131, 132, 1928.

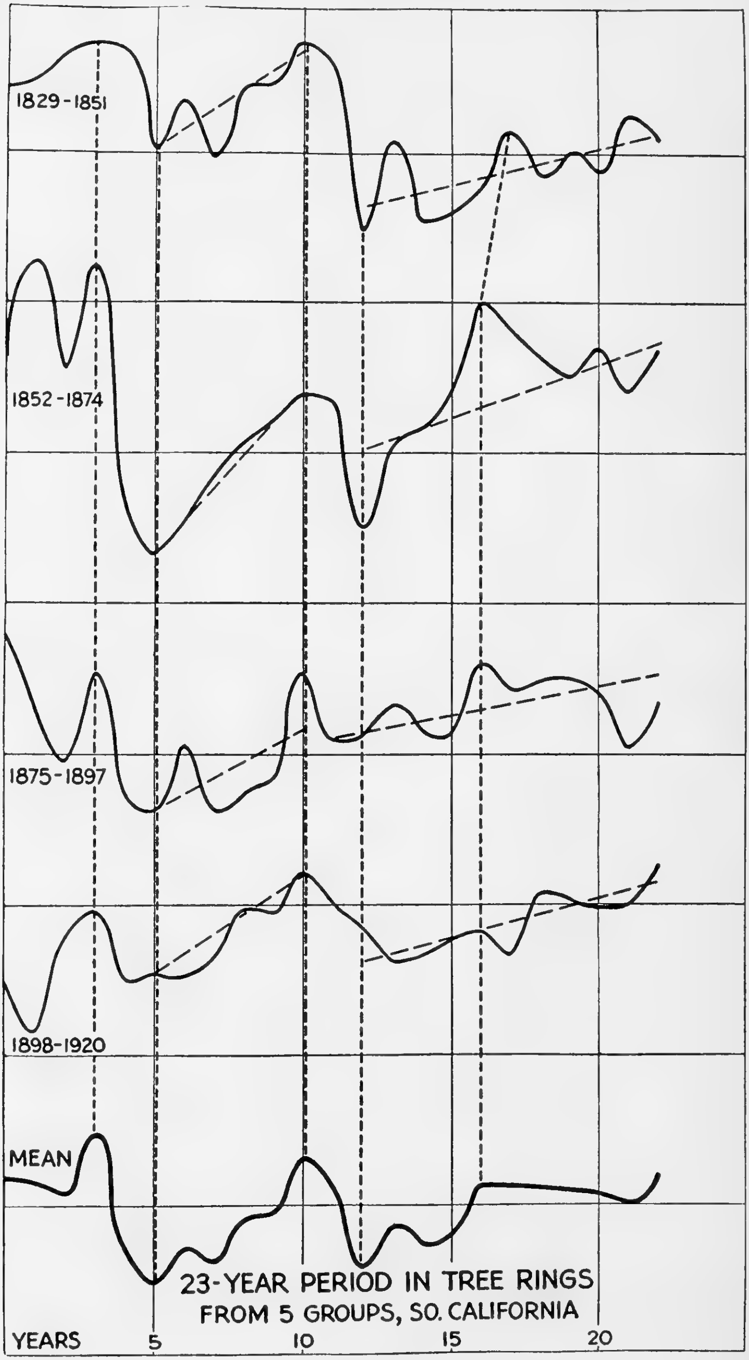
1829-1851
1852-1874
1875-1897
1898-1920
MEAN
23-YEAR PERIOD IN TREE RINGS
FROM 5 GROUPS, SO. CALIFORNIA
YEARS
5
10
15
20

Fig. 4.

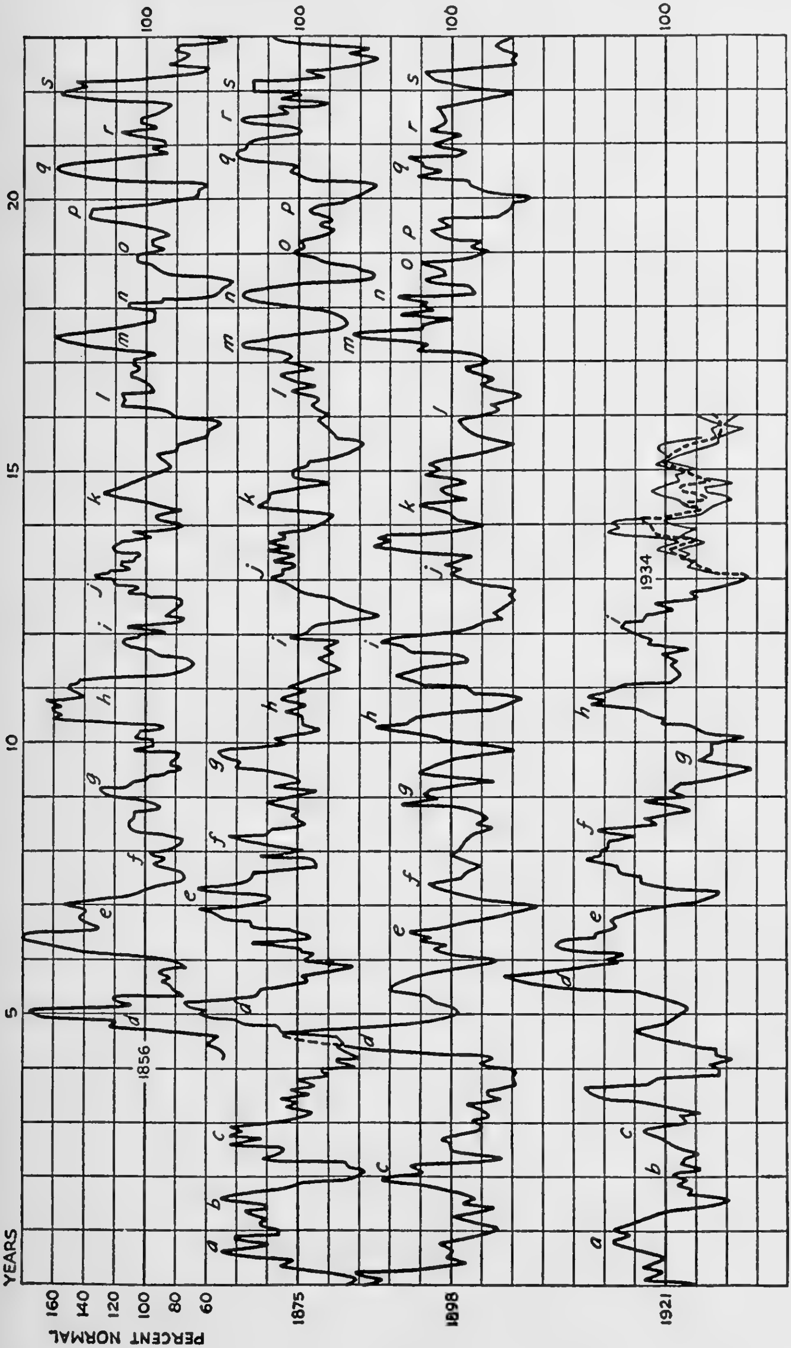

FIG. 5.—The 23-year cycle in precipitation at Peoria, Ill. Corresponding features indicated by letters.

and in April 1901. It might very well be that the changed conditions, as regards snow covering and atmospheric circulation, in these months of three different seasons of the year, would tend to produce changes of phase in the terrestrial response of the weather elements to the regularly recurring solar cause.

I tested this hypothesis for several periods and for a variety of weather stations as indicated in figure 6. In all the graphs of figure 6 the abscissae are the months of the years in which the solar cause recurs, and the ordinates are the months of the period in which the terrestrial response is observed. The latter data were obtained in each case by plotting the successive months of departures from normal weather since 1920 in separate graphs, each of the length to include only one recurrence of the period in question. In each such plot the maximum point was located, and serves to establish one point among the ordinates in figure 6.

Of course the influences of any terrestrial modifying causes, and the influences of other solar periods, would often tend to displace maxima in these working graphs. Hence it is not surprising that the points plotted in figure 6 do not fall exactly upon the straight lines drawn. But it is plain that these straight lines tend strongly to represent the mean indications of the groups of points. I conclude, therefore, that for various solar periods, and for many terrestrial stations, changes of phase in the weather periods, associated with the periodic solar variations, are due to seasonal terrestrial influences, and not to changes of solar phases.

This conclusion reached, phase changes may be eliminated from computations. Consider, for instance, the period of 21 months. Whatever solar phase for this period was operative in January 1900, that same solar phase will have been operative in January of each 7th year, counting from 1900, both before and after, provided successive occurrences of the solar periods do not themselves shift in their phase relations. Similar considerations enable us to compute the years when recurrences of each of the other subordinate solar periods had approximately the same relations to the months of the year. These computations having been made, we were able to select all of the approximately comparable recurrences of each of the solar periods, from the year 1800 to the year 1940.

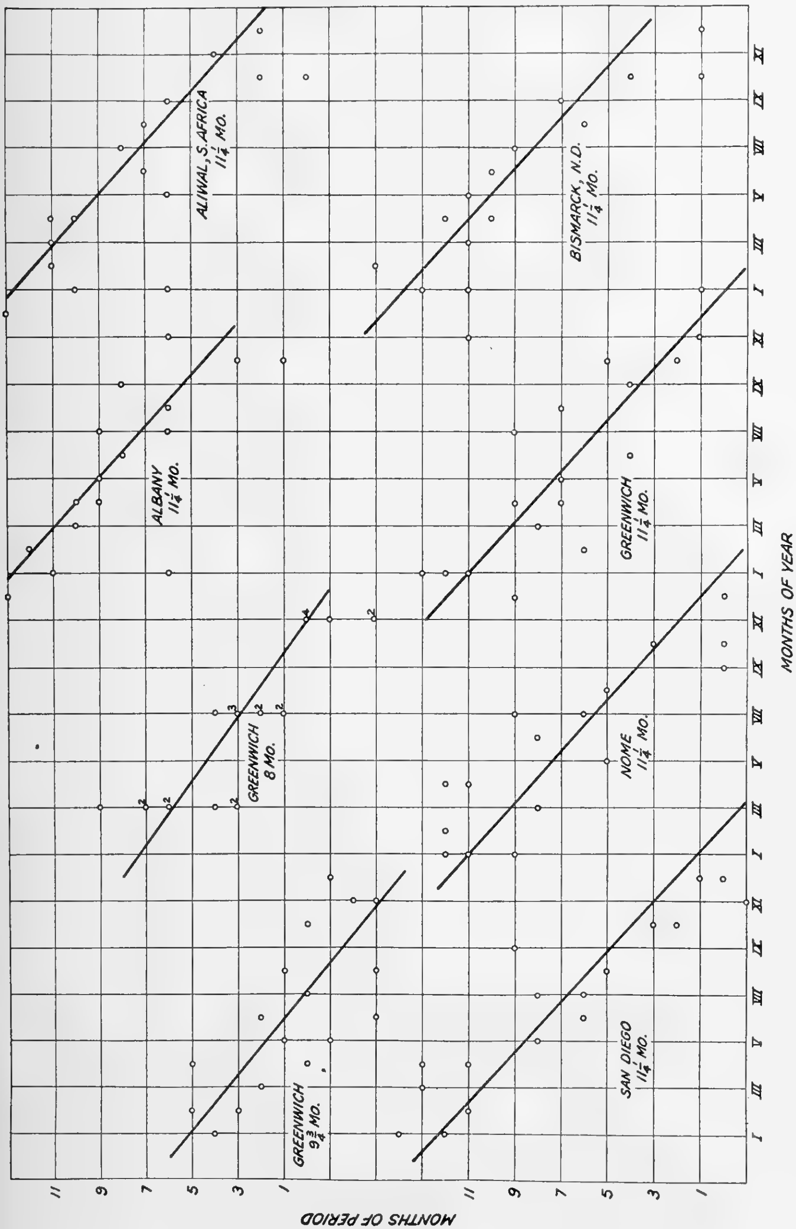

Fig. 6.—Phases of terrestrial effects governed by season of the year when solar causes occur.

METEOROLOGICAL EVIDENCE ON THE REALITY OF PERIODIC SOLAR VARIATIONS, AND ON THEIR EXACT LENGTH

In order to illustrate and develop the evidence, let us make four assumptions, subject to verification.

1. There is a periodic *solar* variation of about 8 months.
2. Its phases are unchangeable.
3. It produces appreciable changes in temperature and precipitation.
4. Its effects on weather are of changeable phase, depending on the relation of the unchangeable solar phases to the season of the year.

If the period is about 8 months, it will recur at the same season of the year after about 24 months. Hence, we shall compare together weather intervals, each 8 months long, which recur at intervals of 2 years. Proceeding in this way, let us employ the departures from normal temperature at Copenhagen, Denmark, beginning with 1800 and smoothed by 5-month consecutive means. These departures have been derived with reference to mean values computed for the interval 1800 to 1932. Thus is formed the following table in which maxima are indicated by bold-faced type, minima by italics.

To test the preferred period we adopt January 1900 as a base date, and working both ways from it, we compute a series of dates $8\frac{1}{8}$ months apart, extending backward to 1798 and forward to 1937. These dates fall in every month of the year. To study them with regard to the seasons and to the passage of the century, the departures for 8-month intervals, beginning with each of these dates, have been arranged in 24 groups. January and February dates taken together are segregated into four groups, covering the years 1800 to 1833, 1834 to 1867, 1868 to 1901, and 1902 to 1935. A similar grouping has been made for each succeeding pair of the months of the year.

The following table gives the data for November and December by individual group means, as well as by the grand mean, and gives the grand means for all other pairs of months. It is seen that there is no progressive side shift of the individual means for November and December. The same is true for the other pairs of months. There is, however, a marked shifting of terrestrial phases governed by the different seasons at which identical solar phases recur. This is indicated in the table by positions of the bold-face and italic numbers corresponding, respectively, to maxima and minima.

The numerical results just set forth appear to confirm the reality of all four of the assumptions made above. The several grand mean values indicate $8\frac{1}{8}$-month periodicities with ranges of from 0°.47 to 1°.44 Centigrade throughout an interval of 139 years. The range depends on the time of the year at which identical solar phases recur.

TABLE 1.—*Copenhagen temperature departures, smoothed. Test of 8-month period*

Values of January to August only

Unit: 1/10 degree C.; for means, 1/100 degree C.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
1800	−19	−17	−47	33	29	−12	− 4	15
2	−15	−11	22	10	−15	−17	−33	6
4	18	−21	−25	− 8	11	3	5	11
6	17	19	− 4	−19	8	−20	−15	9
8	8	−11	−19	−17	9	9	24	26
10	1	− 5	− 2	−16	−27	− 4	8	6
12	− 1	13	−18	−32	−14	− 4	−21	2
14	−53	−53	−29	4	−30	−15	10	− 2
16	4	−22	− 4	− 6	−27	−15	2	−14
18	14	15	20	−21	− 3	11	14	− 2
20	−32	1	− 4	12	0	−15	− 7	− 3
Mean	−53	−64	*−100*	−39	−54	−72	−15	+49

Table of Means

1800 to 1820	−53	−64	*−100*	−39	−54	−72	−15	**+49**
1822 to 1842	*−71*	− 6	**105**	42	8	15	− 4	18
1844 to 1864	*−76*	4	−17	**− 1**	− 9	−11	−52	−30
1866 to 1886	**127**	115	44	85	*−27*	4	35	24
1888 to 1908	**123**	59	25	1	− 1	17	−25	*−64*
1910 to 1930	74	108	**133**	96	58	*−59*	46	−16

The maximum appears to shift 11 months and the minimum 19 months to the right in 110 years. With such large shifts one cannot exactly determine the proper correction to the period with one trial. These shifts however indicate: By the maximum, $\frac{11\times 8}{100\times 12} = \frac{1}{15}$ month. By the minimum, $\frac{19\times 8}{110\times 12} = \frac{1}{9}$ month. Further trials led us to fix on the correction $\frac{1}{8}$ month, and to prefer the period $8\frac{1}{8}$ months.

TABLE 2.—*Copenhagen temperature departures, smoothed. Test of $8\frac{1}{8}$-month period*

Values of all months employed. Means given only

Unit: 1/100 degree C. throughout

Years	November–December beginnings							
1798 to 1833	*—19*	24	21	7	**84**	11	18	— 6
1833 to 1868	*—153*	—55	—48	— 4	—10	—75	—41	—66
1868 to 1903	20	85	88	**103**	33	77	*—23*	— 3
1903 to 1937	*—102*	20	36	**44**	29	— 4	— 5	—20
1798 to 1937	*—79*	22	29	**65**	41	3	—15	—29

1798 to 1937								
Nov. and Dec.	*—79*	22	29	**65**	41	3	—15	—29
Jan. and Feb.	4	— 3	*—32*	34	**59**	— 1	— 7	6
Mar. and Apr.	—29	—29	—64	—19	*—66*	—39	—29	**15**
May and June	— 1	45	44	4	*—12*	24	33	**46**
July and Aug.	29	**38**	—24	— 1	—12	16	8	*—31*
Sept. and Oct.	24	32	**52**	6	*5*	18	40	42

That there is here no progressive secular displacement of the phases of means of groups beginning at a constant season of the year, is shown by the extended table for November–December. But groups beginning at different seasons of the year do show displacement of phases with respect to one another.

This difference in amplitude is due not so much, I think, to a difference in effectiveness per se of the solar cause, as to a fitfulness of the terrestrial dealings with it. From this latter cause individual periods which are combined together in the seasonal means clash together in phase, and so reduce the ranges of the mean.

WEATHER RESPONSES TO THE SUBORDINATE SOLAR PERIODS

We have made use of monthly temperature records [6] from Copenhagen, Vienna, and New Haven, beginning with the year 1800, to investigate the weather responses to 7 of the 10 periodic solar variations. We have first computed the years when the temperature responses to the assumed solar periods must be in approximately corresponding phases, provided that the solar periods recur without displacements of phase and that they have the lengths we had attributed to them.

Before particularly discussing these investigations, I shall make a few remarks on the nature of the periods I have in mind. Many investigators show strong preference for the use of sine and cosine forms in studying periodicities. While it was shown long ago that any curve, however irregular, may be represented by a summation of a series of sine and cosine terms, this is an entirely forced and arbitrary mathematical device. It is so elaborate, in the case of recurring periodic curves of irregular form, that if adhered to with the use of series having sufficient terms to give a true representation, one could not, with ordinary means, find time for such a research as I contemplate here.

It has seemed to me not only simpler, but truer to the actual facts, to test the validity of periodicities, and to express the forms of them, by tabulations of actual ordinates and abscissae, determined in records of the phenomena. One uses enough repetitions of the proposed period in each table to yield a fairly representative mean form, if indeed there results a plausible form, indicative of a real period. Then by comparing the mean forms determined by successive tabulations, one sees whether the proposed period persists throughout the entire interval investigated. By this means one learns whether to reject the period as nonexistent. But one also often detects lateral shiftings in the same sense, among the curves determined by successive tabulations. These shiftings enable a correction to the length of the assumed period to be computed. Then a new tabulation may be made with the improved

[6] World Weather Records, Smithsonian Institution, 1927 and 1934.

period, and, if necessary, a further correction to its length may be made and subjected to a new test by tabulation.

When a very long interval is under consideration, in the examination of relatively short periods, there will be so many repetitions that very exact lengths of the periods must be found, or else in the mean of all recurrences the amplitudes of the periods will disappear. As a corollary it will be plain that of two periods slightly different in length, that is the better for which the average amplitude over a very long interval is the greater.

When using odd lengths of periods, such as 9.79 or 11.29 months, we have first to prepare a table showing the exact day of ending of each recurrence. Thus in our tabulation we must occasionally repeat a month, or omit a month, so as to keep always within ½ month of the true times when the periodicity recurred.

TABLE 3.—*Average march of two assumed periodicities, Copenhagen and New Haven, 1800-1932*

Station	Assumed period Months	I	II	III	IV	V	VI	VII	VIII	Range
Copenhagen	8.00	0°.10	0°.41	—0°.14	—0°.12	—0°.08	—0°.25	—0°.02	—0°.33	0°.74 C.
	8.12	—0°.14	0°.29	0°.55	0°.79	0°.33	—0°.33	—0°.50	—0°.22	1°.29 C.
New Haven	8.00	0°.18	0°.20	—0°.13	—0°.04	0°.25	0°.08	—0°.02	0°.04	0°.38 F.
	8.12	0°.69	0°.45	0°.52	0°.46	0°.17	—0°.08	—0°.62	0°.13	1°.31 F.

To illustrate the necessity of accuracy in the lengths of periods when treating of periodicities in so long an interval as 132 years, I give the results of two sets of analyses. In the first the period of 8.00 months is assumed to exist in the departures from normal temperatures computed for the interval 1800 to 1932 from records of Copenhagen and New Haven. In the second the period is taken as 8.12 months. To avoid seasonal influences, the comparison includes only periods when the solar pulse was in identical phases and running from January to August. Equal numbers of such periods were used in computing each of the results shown in table 3.

It will be seen that in each of the analyses, based on an assumed period of 8.12 months, there results a fairly regularly defined periodic curve of considerable amplitude. The other analyses based on 8.00 months are much less satisfactory. I conceive that the excellent showing of the period of 8.12 months for each of two far-separated stations, and throughout an interval of 132 years, is satisfactory proof of the validity of this period in weather.

To further emphasize and explain the preceding discussion:

With an 8-month period there are 66 even-numbered years from 1800 to 1932 when the terrestrial response should be in the same phase in January. Six tables may be prepared from monthly means of temperature departures at Copenhagen, each covering 11 recurrences. In each table there will be in each line departures for the 8 successive months, January to August, making 8 columns, each column 11 lines long. Taking the mean values of the 8 columns of departures, we obtain the average march of the 8-month period in Copenhagen temperature departures for an interval of 22 years. On comparing the

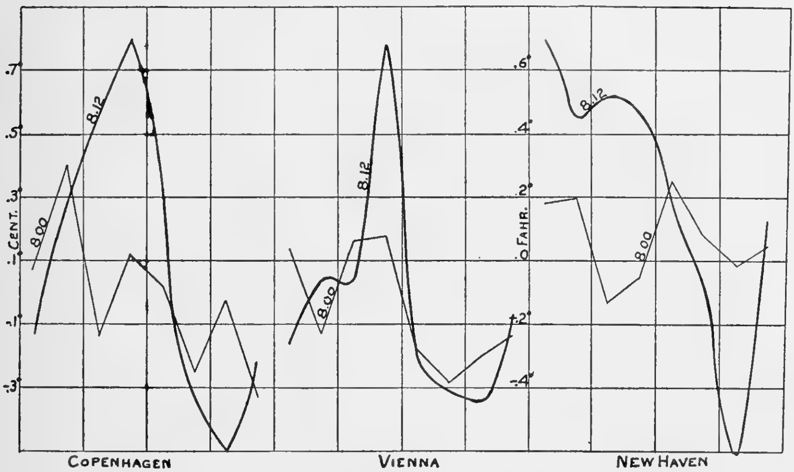

FIG. 7.—Greater amplitudes of periodic curves when precise period is found.

6 mean curves thus obtained we found a slight displacement of maxima and minima from epoch to epoch indicating that not 8.00 but approximately $8\frac{1}{8}$ months is the true period. We have repeated the computation at Copenhagen, at Vienna, and at New Haven with the period $8\frac{1}{8}$ months and employing only such epochs (37 in number) as bring corresponding solar phase dates within less than ± 1 month of January 1. Thus we find the curves given in figure 7 representing the interval 1800 to 1932. The period $8\frac{1}{8}$ months suits all three stations. But compare the ranges of these 3 curves of $8\frac{1}{8}$ months period with the ranges of the other 3 curves of 8.00 months period also given in figure 7. Evidently this slight difference in length of period is highly important for so long an interval as 132 years.

I shall postpone a more detailed report of this investigation which concerns the determination of the exact lengths of the periods. It will probably be published in Volume 6 of the Annals of the Smithsonian Astrophysical Observatory, now in preparation. However, the computations from the three stations, Copenhagen, Vienna, and New Haven, agree very well as to the best lengths of the 10 solar periods.

CONSTANCY OF PHASE IN SOLAR PERIODIC VARIATION

Having observed the solar constant daily for only 20 years, it would be uncertain, if it were not for the meteorological evidence just described, whether the solar periodic variations continued for long intervals, such as a century, without displacements of phase. But if there were frequent displacements of phases in the solar periods then the numerous repetitions of the responding periods in the weather during 132 years would bring out the discrepancy. They would not in that case yield periodic mean weather curves of considerable amplitudes, such as would, if synthesized, reproduce to a considerable extent

Table 4.—*Possible range of solar temperature effects*

Station		Period, months 8.12	9.79	11.29	21.00	25⅓	39½	45½	Sums
		Amplitude in degrees							
Copenhagen	C.	1°.29	0°.79	1°.40	0°.47	1°.00	1°.16	0°.63	6°.74 C.
Vienna	C.	1°.13	1°.20	1°.87	2°.01	0°.99	1°.25	1°.00	9°.45 C.
New Haven	F.	1°.31	1°.90	3°.30	0°.90	1°.70	0°.58	0°.90	10°.59 F.

the range of actual weather fluctuations. So many repetitions, if the periodic causes had different phases, would tend to flatten the general mean curves toward zero amplitude.

Accordingly it is of much interest to assemble the mean periodic weather curves of Copenhagen, Vienna, and New Haven representing the interval of 132 years and see how wide ranges they could produce from extreme crest to extreme trough if made to recur till all came simultaneously to maxima at one epoch, and to minima at another. This assembly is given in table 4. It shows, when we consider only 7 of the 10 known periods, that they are of sufficient combined range to account for the full ranges of smoothed monthly mean temperature departures from the normal at Copenhagen, Vienna, and New Haven. I suppose that the observed ranges of temperature departures from the normal at these stations are actually less than might result from solar variation alone for the following reason. Since there are terrestrial phase changes as explained above, and since the periods are not exactly commensurable, the 10 periodic solar causes, in fact, are never in complete harmony of phase as to maxima and minima of their temperature effects. Weather changes produced by solar variation, in other words, can never exactly repeat, because of terrestrial phase changes, and of the noncommensurability of the solar periods.

ANALYSIS AND SYNTHESIS OF SOLAR VARIATION

These meteorological researches having, as I conceive, fixed the lengths of the solar periods with considerable accuracy, I now present the analysis of the curve of solar variation for the years 1920 to 1939. It is derived from Montezuma observations alone after the year 1923 and from combined results of Montezuma and Harqua Hala from 1920 to 1923. I used these data from our best station of the years 1923 to 1939 for this purpose before the completion of revisions of data from other stations. As shown in figure 1, the agreement of the monthly means from different stations is so good that I have no reason to think the results would be much changed had the final data combined from all stations been available.

In figure 8, curve A comprises these monthly mean observations of the solar constant for 20 years. The analysis of the curve was made as described in my paper "Solar Radiation and Weather Studies,"[7] and in my paper "The Variations of the Solar Constant and Their Relations to Weather."[8] Seven of the periods used were those given above, and, in addition 68, 91, and 276 months. The results of the analyses are printed in the legend for figure 8. In making these analyses, we verified the constancy of the phases by dividing the 20 years of data into several parts for the shorter periods.

Curve B is computed by synthesizing the 10 periodic curves indicated by numbers below it. It is obviously very like curve A. The average monthly deviation for 240 months between curves A and B is 0.0026 calorie, or 0.13 percent.

AMPLITUDES OF THE SOLAR PERIODS

Having satisfied ourselves, as explained above, that there has been no notable change in the orderly succession of phases in the subordinate solar periods for 140 years, it is of interest to know if the amplitudes of these periods also remain unchanged. Here we have to rely on the solar observations of the past 20 years alone. So far as we see, the meteorological records cannot help to solve this question.

It would be expected, by analogy with the sunspot numbers, that these amplitudes will change. Our meager data of only 20 years dura-

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[7] Smithsonian Misc. Coll., vol. 94, No. 10, 1935.

[8] Quart. Journ. Roy. Meteorol. Soc., vol. 65, No. 280, 1939.

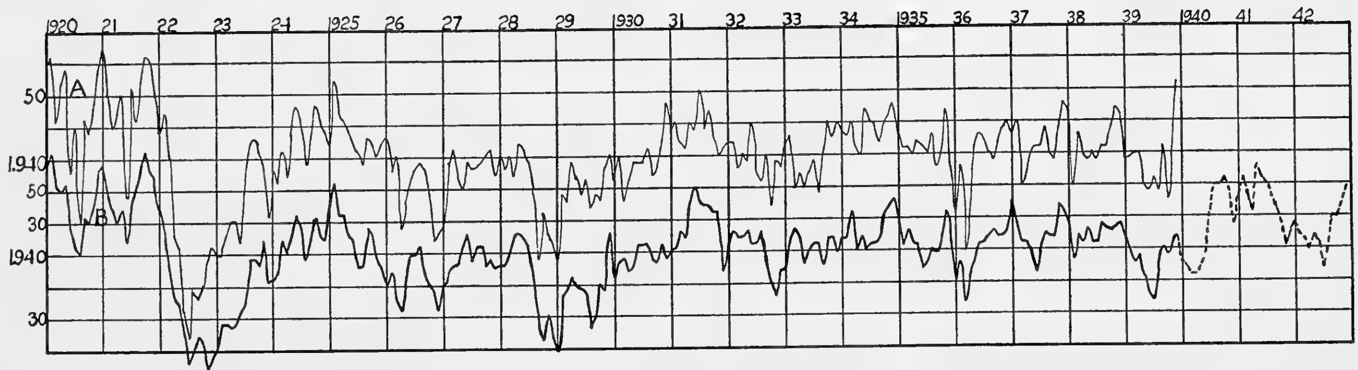

FIG. 8.—Curve A, monthly mean solar-constant values, Montezuma, Chile; Curve B, synthesis of the following 10 periodicities, beginning January 1920. Unit, $\frac{1}{10,000}$ calorie; phases below begin January 1926.

Length in months	
$8\frac{1}{8}$:	—8, 3, —6, —7, 7, 16, 3, —9.
9.79:	7, 3, —3, —11, —7, 4, —3, —3, 7, 4.
11.29:	—11, —12, —18, —14, 8, 19, 17, 11, 19, —10, —8.
21.00:	—15, —7, —6, —11, —18, 4, 8, 13, —9, 5, 5, —8, 9, 23, 18, —8, 24, 2, —6.
$25\frac{1}{3}$:	0, 11, 16, (23), 30, 16, —1, 2, —11, —25, —22, —26, —12, —10, —3, 20, 11, 15, —8, —15, —4, —25, 6, 4, 12, 18.
$39\frac{1}{2}$:	—40, —45, —57, —68, —68, —53, —11, —7, —4, —4, —3, —3, —2, —2, —1, 1, 3, 22, 30, 42, 41, 41, 34, 35, 37, 41, 45, 53, 61, 51, 41, 11, —5, —17, —27, —35, —40, —45, —44.
$45\frac{1}{4}$:	—10, —15, —20, —24, —25, —25, —25, —24, —23, —22, —18, —15, —10, —6, —5, —2, 0, 0, 0, 3, 5, 6, 7, 8, 9, 10, 11, 11, 12, 13, 14, 14, 14, 15, 15, 15, 15, 15, 15, 15, 14, 10, 7, 0, —4.
68.00:	36, 27, 22, 16, 18, 19, 20, 21, 16, 14, 8, 7, 6, 7, 8, 10, 12, 13, 12, 12, 10, —1, —3, —12, —19, —23, —30, —34, —43, —49, —53, —54, —57, —56, —54, —48, —44, —34, —33, —24, —20, —13, —10, —9, —3, —1, 2, 5, 7, 7, 11, 12, 13, 14, 14, 15, 15, 15, 15, 15, 14, 12, 11, 7, 60, 56, 52, 42.
91.00:	10, 18, 22, 24, 24, 22, 20, 18, 17, 15, 15, 44, 10, 7, 5, 0, —5, —8, —12, 8, 10, 16, 18, 18, 17, 14, 10, 0, —5, —5, —8, —8, —8, —7, —6, —6, —6, —6, —5, —4, —3, —4, —5, —8, —10, —14, —15, —18, —23, —24, —22, —20, —18, —17, —15, —13, —12, —10, —9, —8, —7, —6, —5, —5, —4, —4, —3, —2, —1, —1, 0, 2, 3, 3, 3, 3, 3, 4, 4, 4, 4, 3, 2, 1, 0, —3, —5, —5, —3, 0, 5.
23-year:	—24, —40, —36, —3, —5, —16, —2, 24, 29, 17, —4, —6, 16, 33, 39, 41, 39, 34, 29, 7, —14, —20 —18.

tion cannot give indications as to the longer periods. But we have explored the 8.12-, 9.89-, and 11.29-month periods as to their amplitudes since 1920. For this purpose we prepared tables of 10 lines for the 8.12-month period, of 8 lines for the 9.79-month period, and of 7 lines for the 11.29-month period. Taking the mean values for these several arrangements, we can compare average amplitudes at three epochs during the 20 years of observation. Of course, the mean values for tables of so few lines are not very reliable, considering that influences of accidental error and of interference by others of the 10 periodicities are simultaneously operative. But for such worth as they may have the comparative results are as follows:

Relative amplitudes of solar periodicities in three epochs

	Periodicity, months		
Epoch	8.12	9.79	11.29
Jan. 1920–June 1926	49	83	105
July 1926–Dec. 1932	26	39	39
Jan. 1933–June 1939	36	38	54

All three periodicities seem to be stronger in the first epoch, 1920-1926, than later. But the data are not sufficient to be decisive.

SYNTHETIC WEATHER PREDICTIONS

It appears that 10 periodic variations of the sun have persisted in regular phase relations for 20 years, and probably for 140 years. They are each apparently associated with periodic departures from normal temperatures, and also (although to save space we have not illustrated it) with periodic departures from normal precipitation. For the periods of shorter lengths these departures from normal weather conditions exhibit phase changes. But these phase-changes in weather seem to depend on the season of the year when the solar cause operates, and can be allowed for on that basis. The solar periodicities may not be of uniform amplitude as they recur, but this matter is uncertain as yet.

These facts led me to consider if weather might be predicted by a synthesis of the average effects of the periodic solar causes, just as the solar variation is itself predicted for the last years shown in figure 8.

With the assistance of Miss N. M. McCandlish in the computing, we have tried 5-year predictions for various stations, both for precipitation and temperature. Using only the recorded weather data up to December 1934 as a basis for the forecasts, we have made synthetic predictions for the later years, 1935 to 1939. These predictions were then compared with the observed weather records of 1935 to 1939, but these latter records had no part in influencing the computations of synthetic weather indications.

In illustration of the method I give in table 5 the components of a synthetization of 1 year in the precipitation of Peoria, Ill. In figure 9 I give predicted and observed weather for 5-year periods in several stations. As these long periodicities cannot have to do with the vicissitudes occurring within individual months, I use 5-month running means of departures in weather data in these illustrations.

Considerable similarity appears between predictions and events. On the average about two-thirds of the months of a 5-year prediction seem to show fairly good correspondence. Some stations turn out better than others. For another somewhat better synthetic prediction of the precipitation at Peoria, Ill., not here illustrated, I have worked out the correlation coefficient between prediction and event over a 60-month interval. It results 70 ± 5 percent.

TABLE 5.—*Synthesis of precipitation, Peoria, Ill., for the year 1938* [a]

Percentages of normal. 5-month running means

Period, months	8	9¾ [b]	11¼ [b]	21	25	39½	46	68	Forecast (Product) [c]	Observed
Jan.	97	82	100	98	122	123	101	95	112	134
Feb.	98	86	100	93	121	120	97	100	110	147
Mar.	98	90	101	93	108	122	122	96	128	156
Apr.	98	95	99	103	91	139	137	87	143	145
May	100	103	101	112	85	121	137	84	138	156
June	103	103	106	114	76	125	144	80	140	143
July	103	101	97	111	81	116	138	88	128	131
Aug.	103	95	93	108	88	106	105	94	90	109
Sept.	102	99	93	101	97	77	97	98	67	86
Oct.	101	103	96	92	101	69	89	104	59	66
Nov.	97	103	97	95	104	79	102	102	79	85
Dec.	98	106	98	93	95	102	99	96	87	103

[a] The periods used differ slightly from those now preferred.
[b] Where dashes are inserted in these columns, changed forms of periods begin, according with the control of periods by season of the year, above explained.
[c] This forecast would be improved if it lay 10 percent higher. Its range of 84 percent compares with the observed range of 90 percent favorably, and its phases are quite correct.

What seems to me particularly significant in these comparisons is this: The range of departures forecasted is nearly as great as the range observed. If the solar variations were negligible in their effects, or even nonexistent, then the average weather effects corresponding to them over a period of 20 to 50 years, which are the basic elements in our forecast, would also tend to be negligible. Moreover, if they had no common thread of causation connecting the several solar periods with the weather, then the synthesis of these supposed spurious or negligible average weather periodicities would tend to be zero. On the contrary we find their synthetization gives values of weather departures which show nearly the same ranges and phases as the actual weather records. To me this indicates that the variation of the sun is actually a principal cause of weather changes.

This method of forecasting by synthesis of periodic effects, like that about to be mentioned, while hopefully successful in many cases, shows bad timing or dissimilarity with events in others which destroys its

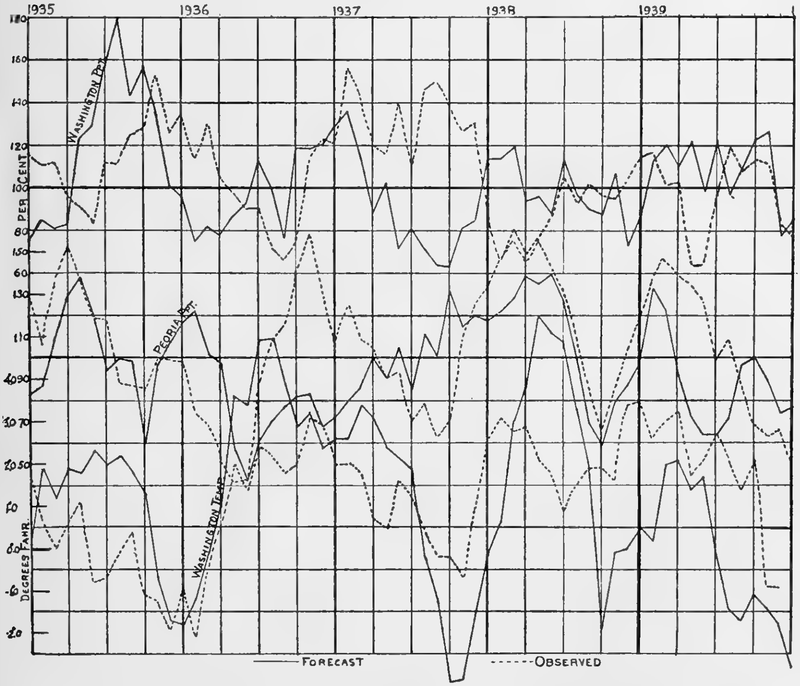

FIG. 9.—Predictions of weather based on the previous effects of 10 periodic changes in solar radiation.

usefulness. There appears to be some other variable, as yet obscure, which must be discoverèd and applied before valuable forecasts can be made consistently by this method.

WEATHER FORECASTS BASED ON 23-YEAR CYCLES

With further regard to long-range forecasts depending on solar variation, as I remarked above, the solar periodicities approach rather closely to a least common multiple in 23 years. But this relationship is not exact. Moreover, the seasonal phase change of terrestrial response to corresponding solar causes of weather effects complicates the matter. Hence the phases and amplitudes of weather features should not exactly recur at intervals of 23 years, even if there were no other terrestrial complications. Yet the tendency to a repetition of weather features each 23 years, such as is shown in figure 5, itself affords a method of long-range forecasting which gives some promise of usefulness. It may be compared in its results with the synthetic method explained above.

In applying this method, one must first determine with what displacements in phase the weather features happening recently occur with respect to those of 23, 46, and 69 years ago. Also one must be guided as regards amplitudes by those former appearances. One pieces his prediction onto the curve of departures as it stood at the time the forecast began, and thus accepts the prevailing trend, whether positive or negative, as a point of departure.

I now give in figure 10 several examples of forecasts and events with which I have tested this method in the past 6 years. Here, as in figure 9, the data used are 5-month running mean values of departures from the normal.

The forecasts shown in figure 10 were all made previous to the events. While records of 23 or 46 years preceding are shown in the figure by way of illustration, other preceding data were also considered in making the predictions.

It will be seen that the forecast for 1934, 1935, and 1936 of precipitation at Burlington, Vt., is very good. Other forecasts have lesser accordance with events. As a rule, precipitation seems more amenable to this kind of forecasting than temperature. This is also the case with synthetic forecasts previously explained. However, in almost all cases of failure, the trouble seems to be, not that coming weather features were unperceived, but that differences of timing of as much as 3, or even 4 months occur, as between the prediction and the event. This of course destroys the usefulness of the method.

It appears that other factors, still obscure, must be discovered, whereby these errors of timing may be anticipated and corrected, before this method of forecasting can be very useful. Nevertheless there seems to me to be so much evidence that the periodic solar variations, and their cycles of approximately 23 years and multiples thereof, are governing influences over weather, that I cannot but hope that experts in meteorology will take up this clue, and go forward to greater success, by combining with it their own knowledge of atmospheric processes.

Much more might be said of these long-range solar periods, and their application to weather forecasts. Indeed, without additional details, the statements made here may be thought by some readers to rest too much on the good faith of the narrator. But this paper has already exceeded its intended limits, and as I wish still to bring up the subject

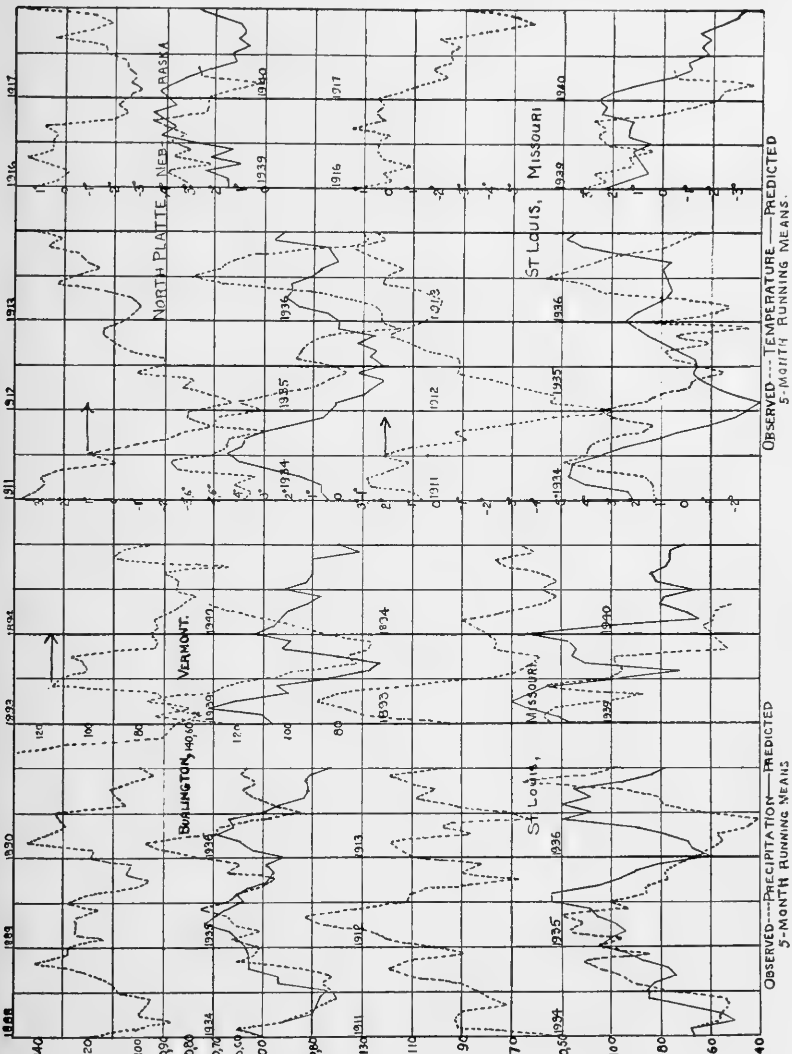

FIG. 10.—Predictions of weather based on the 23-year cycle.

of short-time solar changes and their weather effects, I will say no more of very long-range weather prediction.

SHORT-INTERVAL SOLAR CHANGES

The sun is not equally bright at all points on its surface. This is visually obvious with regard to sunspots and faculae. My colleagues, Fowle and Arctowski, as well as H. H. Clayton, have demonstrated correlation between solar appearances and variation of observed solar radiation.[9] As the sun rotates upon its axis in approximately 27 days, a succession of unequally radiant solar surfaces is presented toward the earth. This leads to irregular variations of the solar constant of short intervals. There is a tendency, also, to create families of solar changes of about 27 days' period. However, the changes in the sun's surface are so rapid that generally new distributions of brightness take place before more than one or two solar rotations are completed. The local variations of solar brightness usually produce very small percentage changes in the sun's total radiation. On these accounts it is only rarely that the 27-day period can be distinctly shown by our still unsatisfactorily accurate solar-constant values. However, some good cases are on record.[10]

In two papers I have discussed the effects of short-interval solar variation on the temperatures of Washington, St. Louis, and Helena in the United States, and Potsdam in Germany.[11] Now that longer series of daily solar-constant values are available, I have recently repeated in part the computations described in these papers, using 20 years instead of 12 years of observations. The results of these recent studies do not alter the conclusions that opposite trends of temperature follow, respectively, rising and falling sequences of solar change, and that these temperature changes are of major significance. I have treated the subject as well as I can in my paper in reply to Paranjpe and Brunt,[12] and will now quote therefrom:

Referring to figure 1 of my just cited paper, here reproduced,[13] the reader will find there two curves for each month of the year showing departures from normal temperature at Washington, D. C. In each month the curves show a well-marked opposition like the right and left hands. The separations of the curves in the months January, February, March, April, May, June, August, October, November, and December range from 14° to 24° F., and evidently constitute major departures from normal temperatures. Similarly, results showing in almost all cases opposition like the right and left hands, but differing widely in actual march of the pairs of curves, are shown for St. Louis, Helena, and Potsdam in other illustrations in the cited publications. The curves are computed for all these cities starting from identical dates, 320 in number, scattered over 12 years. Some 10 to 20 cases are combined in each curve shown. The

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[9] See Smithsonian Misc. Coll., vol. 77, No. 5, pp. 21-23, 1925; also Proc. Nat. Acad. Sci., vol. 26, No. 6, pp. 406-411, 1940.

[10] See, for instance, Smithsonian Misc. Coll., vol. 69, No. 6, pp. 7-8, Sec. (3), and the curve for 1915, fig. 1, 1918. See also my paper in Science, April 11, 1941.

[11] Smithsonian Misc. Coll., vol. 95, No. 12 and No. 15, 1936.

[12] Quart. Journ. Roy. Meteorol. Soc., vol. 65, No. 280, 1939.

[13] Here again reproduced as figure 11 of this paper.

data of temperature departures in each case cover 16 days following the starting date selected.

How were these 320 dates selected? They are chosen as dates when solar variations commenced. As shown in figure 1 and table 1 of "The Dependence of Terrestrial Temperatures on the Variations of the Sun's Radiation," they

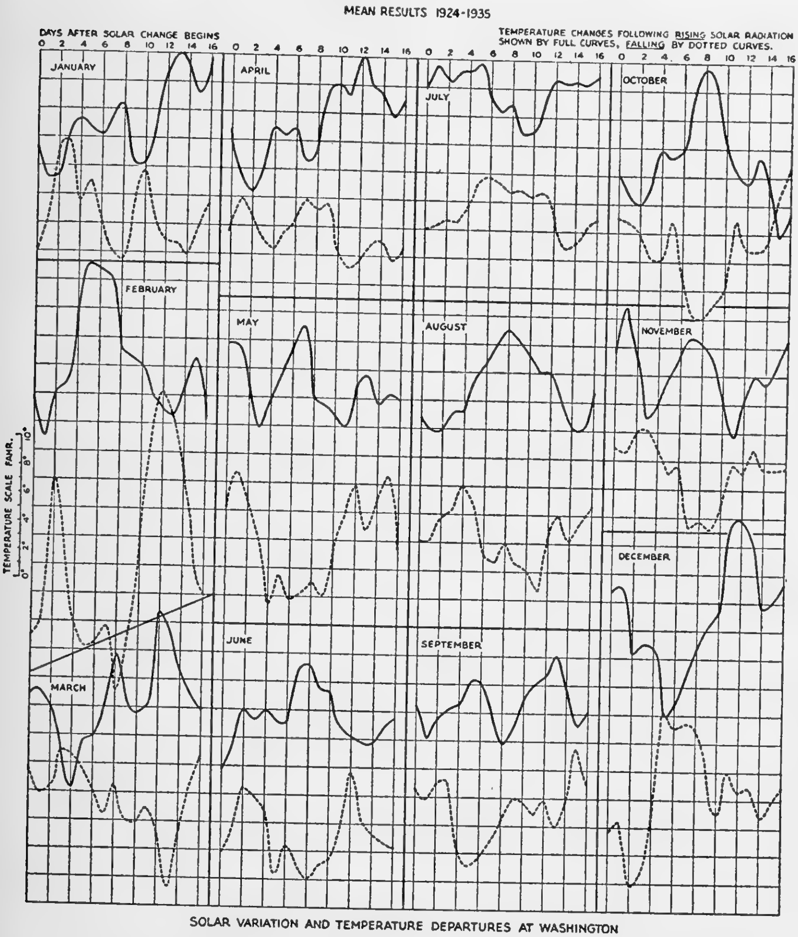

FIG. 11.—Oppositeness of temperature departures at Washington which follow average rising and falling sequences of solar variation.

comprise all the dates during 12 years when good consecutive solar-constant observations, made mostly at Montezuma, Chile, began to indicate rising or falling sequences of the sun's output of radiation. The range of these sequences is only about 0.7 percent of the solar constant. Owing to the interference caused by changes in atmospheric transparency, superposed on the inevitable accidental errors of measurement, it is highly probable that some of these 320 cases are spurious. If the spurious cases could be eliminated the average temperature departures would doubtless be increased above their already large magnitudes.

The plain inference from these data is that short-interval solar changes are major causes, controlling weather for many days. It is so unexpected that I made other checks, described as follows:

. . . . as I showed in my paper, "The Dependence of Terrestrial Temperatures on the Variations of the Sun's Radiation," above cited, not only do several cities show large opposing trends of temperature following rising and falling sequences of observed solar variation, but 46 cases of unusually great observed solar changes were followed on the average by 1.95 times as large temperature changes in the same phases as the mean of 150 cases of all amplitudes. Again, the average trends of temperature following solar changes, as observed in the years 1924 to 1930, were nearly identical in phase, magnitude, and form with those observed in the years 1931 to 1935.

But now I offer a new evidence which I think is even more convincing. If, in reality, the observed variations of the sun were real, and influenced temperatures greatly for 16 days *after* their incidence, there still seems no reason to think there should have been any unusual temperature effects immediately *before* their occurrence. I have therefore computed for each of the 320 dates the march of temperature departures from normal for 16 days *preceding* the dates in question. I have then computed correlation coefficients for Washington as between the average marches of temperature attending rising and falling solar sequences, both *after* and *before* the beginnings of the sequences of solar change.

To fix ideas, I recall that in each division of this test there are 24 lines comprising 17 values each, two lines for each month of the year, selected from the 12 years 1924 to 1935. These pairs of 24 lines of the divisions are separated into two types, one type containing 17 values for days following, and 17 for days preceding the beginning of sequences of observed *rising* solar radiation. The other type comprises 17 values for days following and 17 values for days preceding the beginning of sequences of observed *falling* solar radiation. Two correlation coefficients are to be computed, one including the 204 values of the two contrasted types *following* the supposed critical dates, the other for the 204 values of the two types *preceding* them.

In order to avoid diluting the correlations by including extraneous influences due to previous conditions, each line was first reduced to the level of zero temperature departure, by adding to all 17 values in that line a constant quantity such as to make the average temperature departure for that line zero.

Having thus arranged the values, correlation coefficients were computed between the two types for the two divisions. They resulted as follows:

After appearance of solar change, $r = -54.3 \pm 4.9$ percent, which is significant.

Before appearance of solar change, $r = +11.1 \pm 6.0$ percent, which is meaningless.

The inference is obvious that the 320 dates, above described, were dates of real significance, since no other consideration was used in selecting them, and it is difficult to avoid the conclusion that they were dates when real solar changes began.

Are such small solar changes adequate to produce the apparent effects?

Sir George Simpson in his classic paper, "Further Studies in Terrestrial Radiation" (Simpson, 1928), concludes that 1 percent change of solar radiation might make up to 2° C. average change in the radiative temperature of the earth's surface, but he says that this change would not be distributed uniformly. As a matter of fact, the temperature at any single station is strongly associated with the direction of the wind. The direction of the wind depends on the location of the station with respect to cyclonic centers. Any cause which alters the paths of cyclonic wind movements, alters wind directions and temperatures greatly. Clayton, from statistical studies, finds that variations of the sun, whether indicated by sunspot numbers or by solar-constant observations, are associated with large geographic changes of the centers of the barometric lows and highs. Hence, although a 0.7 percent change of solar radiation cannot produce all over the earth's surface coincidentally a change in the same direction of 5° or 10° F. in temperature, it may very well produce on a given day a rise of 5° or 10° in one place, accompanied by a fall of 5° or 10° in another place. And this indeed is quite in agreement with the comparative results given in figures 1 and 6 of my paper, "The Dependence of Terrestrial Temperatures on the Variations of the Sun's Radiation."

SUMMARY

The preceding paper covers the following points:

1. Evidence that solar variation has been observed by independent stations in the northern and southern hemispheres with amplitudes as much as 18 times the probable error of the mean of the observations as deduced from their average differences.

2. The reality of solar variation is confirmed by many other correlations, including studies of the distribution of brightness across the sun's disk, the spectral distribution of apparent solar variation, its relation to sunspot numbers, and to faculae and flocculae, the 27-day period in solar variation, and relations to atmospheric temperature and pressure.

3. Ten long periods in solar variation are found, ranging from 8 to 273 months. These have nearly a common multiple in 273 months.

4. These solar periods are traceable in terrestrial temperature and precipitation, but phases of terrestrial responses vary with seasons.

5. By analysis of temperature and precipitation records of Copenhagen, Vienna, and New Haven, it is shown that the solar periodicities continued with unaltered phase for at least 140 years, and produced temperature responses apparently competent in their aggregate to account for the total range of departures from normal temperature.

6. Attempts to forecast weather conditions for 5 years in advance by evaluating the solar influences from past weather records and synthesizing them, proved fairly successful.

7. Attempts to forecast weather conditions for 3 years in advance by using the master cycle of 23 years proved fairly successful.

8. Day-to-day changes in solar radiation, largely influenced by the sun's rotation, appear to be major factors in controlling weather for 2 weeks in advance.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 101, NUMBER 2

A NEW SALAMANDER OF THE GENUS GYRINOPHILUS FROM THE SOUTHERN APPALACHIANS

(With One Plate)

BY
M. B. MITTLEMAN
Ohio University
AND
HARRY G. M. JOPSON
Bridgewater College

(Publication 3638)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
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By M. B. MITTLEMAN,
Ohio University[1]

AND

HARRY G. M. JOPSON,
Bridgewater College[2]

(With One Plate)

Some few years ago the junior author chanced upon a single salamander of the genus *Gyrinophilus* while collecting in a small stream near Caesars Head, S. C., which could not be assigned to any known species in the genus. Discussion with Dr. E. R. Dunn, and an examination of the specimen by him, disclosed that it might possibly represent an undescribed form. However, no further specimens could be obtained until E. B. Chamberlin of the Charleston Museum kindly lent the junior author a single adult *Gyrinophilus* which he had collected at Rocky Bottom, Pickens County, S. C., and which is plainly referable to the same form as the Caesars Head specimen. In view of the paucity of material, it was deemed best to withold description of the animal until such a time as further specimens might appear.

In the course of a revision of the genus *Gyrinophilus,* the senior author accidentally chanced upon the same form, represented in the collection of the United States National Museum by the Caesars Head specimen. Since additional material has become available, and with it a more accurate picture of the variation and distribution of the animal, the following description and notes are offered pending the publication by the senior author of a paper dealing with the entire genus.

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[1] Contribution No. 23, from the Department of Zoology, Ohio University, Athens, Ohio.

[2] Contribution from the Department of Biology, Bridgewater College, Bridgewater, Va.

GYRINOPHILUS DUNNI, new species

PLATE 1

Gyrinophilus porphyriticus dunni STEJNEGER, Rep. U. S. Nat. Mus. for 1937, p. 30 (*nomen nudem*).

Type.—U.S.N.M. No. 113230 (Mittleman Coll. No. 382), female, collected on the campus of Clemson College, Clemson, Pickens County, S. C., 700 feet altitude, by Arnold Grobman, April 8, 1941.

Paratypes.—U.S.N.M. No. 102440, Caesars Head, Greenville County, S. C., 3,000 feet; U.S.N.M. No. 102441, larva, Rabun Gap, Rabun County, Ga., 2,300 feet; U.S.N.M. No. 68168, Jefferson City, Jefferson County, Tenn., 1,250 feet; U.S.N.M. No. 68820, Indian Cave, near Jefferson City, Jefferson County, Tenn., 1,200 feet; Three Springs, near Russellville, Hawkins County, Tenn., 1,350 feet; Charleston Museum No. 35.141.12, Rocky Bottom, Pickens County, S. C., 2,000 feet; Charleston Museum No. 28.144.4, larva, Greenville, Greenville County, S. C., 1,000 feet; Sherman C. Bishop collection, one specimen from Sunburst, Haywood County, N. C., 3,400 feet; North Carolina State Museum No. 4905, Cane River, Yancey County, N. C., 3,000 feet; North Carolina State Museum No. 7594, Clemson College, Pickens County, S. C., 700 feet; North Carolina State Museum No. 7198, Cowee Mountains, between Jackson and Macon Counties, N. C., 3,000 feet; M. B. Mittleman collection Nos. 383-4, Clemson College, Pickens County, S. C., 700 feet; Clemson College Division Ent. and Zool. Nos. 36 and 58, Clemson College, Pickens County, S. C., 700 feet; Clemson College Division Ent. and Zool. No. 105, Walhalla, Oconee County, S. C., 1,000 feet.

Diagnosis.—A *Gyrinophilus* which is red in life, with numerous tiny black dorsal flecks on head, limbs, body, and tail; throat pale, without dark reticulations; venter usually immaculate, or else with a few very small, dark flecks; canthus rostralis with a white orbito-labial line which is heavily bordered with black beneath, and imperfectly bordered with black above; vomerines meeting the parasphenoids at an acute angle; maximum size less than 160 mm. (average total length of type series, 125 mm.).

Description of type.—Costal grooves 18 (including one axillary and two inguinal branches); 7 coastal grooves between appressed toes; head width 13.62 percent of length from snout to vent; head length 14.20 percent of length from snout to vent; eye slightly shorter than the distance from its anterior angle to the nostril; snout swollen, a small tubercle at lower end of nasolabial groove; canthus rostralis prominent; outline of jaw sinuous in its lateral aspect; angle of jaw posterior to the posterior angle of eye; both eyelids fitting under a fold of skin at their posterior angle; a groove extending posteriorly from the eye almost to the gular fold, but intercepted by a small intervening fold; limbs well developed; fingers 3-2-4-1, in order of length, barely webbed at base; toes 3-4-2-5-1, in order of length, first toe half webbed, other toes very slightly webbed at base; vent grooved; tail shorter than head and body, much compressed, keeled prominently except on the basal portion; vomerine teeth 8-8 in series, commencing about half their length beyond the outer border of the inner nares, and curved anteriorly to become confluent with the parasphenoids at an acute angle; parasphenoids extending posteriorly beyond the rictus of the jaws for a distance equal to half their length, and separated their entire length by a distance approximately equal to half the length of a vomerine series; coloration in life, reddish, with thickly scattered minute brown flecks; coloration in alcohol, yellowish tan above, with brown flecks; the narrow, white orbitolabial line of canthus rostralis bordered heavily beneath with blackish, imperfectly lined above with same; dorsal flecks of body assuming the vague outlines of chevrons; labial region with numerous heavy, black bars, which tend to form reticulations; venter of head, limbs, body, and tail immaculate, except for a very few tiny flecks; heavy flecking of dorsum abruptly diminishing on the lateral areas, to become almost completely absent on the ventrolateral surfaces. Measurements: Total length, 136 mm.; snout to gular fold, 17 mm.; head width, 12.5 mm.; snout to anus, 82.5 mm.; tail, 53.5 mm.

Distribution.—The southern Appalachian uplift below 3,500 feet, in North Carolina, South Carolina, Tennessee, and Georgia.

Remarks.—The range of *G. dunni* may possibly extend as far south as northern Jackson County, Ala.; Dunn (1926, p. 266) includes a record for *"Gyrinophilus porphyriticus"* from Sand Mountain, recorded by Holt, which is within the expected range of the new species.

The new form is considered a species rather than a subspecies because of the lack of what may be considered intermediate material between *dunni* and *danielsi*. Although this intergradation will probably be shown to exist some day, we prefer the binomial in view of the absence of the critical specimens. Certain specimens are extant from higher localities (above 3,500 feet) in North Carolina that are not referable to *dunni* nor to *danielsi;* these specimens may ultimately be shown to be either an undescribed form or intergrades between *dunni* and *danielsi.* Similar-appearing specimens from

Tennessee have been referred to by King (1939, p. 554) as *danielsi* × *duryi*. We do not agree with these conclusions, and a future paper by the senior author will deal more thoroughly with these forms. Undoubtedly, however, *dunni* is commoner in collections than present records would indicate; numerous specimens are undoubtedly extant under the name *Gyrinophilus p. danielsi*.

The principal variation observed in available specimens is in the distribution of the dorsal flecks. These vary from very tiny, close-set flecks, which grossly present an irorated appearance, to somewhat larger spots. In no case, however, do these marks approach the size of those found in *danielsi*, nor is there ever the coalescence of markings in *dunni* that so frequently appears in *danielsi*. Occasional examples of *dunni* tend to have the dorsal markings arranged so as to present the appearance of short series of chevrons. Typically, there is a heavily barred or reticulated labial region, but a few specimens show only a lightly spotted or flecked surface. There are often a few very tiny spots or flecks widely distributed on the venter, but in no case is the ventral surface so heavily suffused with markings as it is in *danielsi;* indeed, it is generally immaculate. Costal grooves between appressed toes vary from 4 to 8, average 6.2. The angle of the vomerines with the parasphenoids is occasionally as acute as 45°, but never as obtuse as 90°. Available specimens tend to show that *dunni* is a considerably smaller animal than *danielsi;* as stated previously, the type series averages 125 mm. in total length of body plus tail. Only two specimens are larger than the type, both of these being 160 mm. in total length. Other than these, the type series, which is composed of sexually mature individuals, varies from 100 to 136 mm.

Dunn (1926, p. 271) has postulated that *danielsi* is probably more primitive than *porphyriticus,* and to this we add the hypothesis that *dunni* is mostly likely parental to *danielsi*. It would seem that *danielsi* has arisen from the more widespread, generalized *dunni* stock, and has become differentiated in its ecological niche, which, judging by the large size and robust form attained, has proved to be a favorable one.

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The senior author is indebted for advice and the loan of specimens to Dr. Sherman C. Bishop, Dr. Doris M. Cochran, Prof. Franklin Sherman, C. S. Brimley, and Dr. Willis King. A special word of thanks is due to Dr. Herschel T. Gier, of Ohio University, for his many fruitful criticisms and unfailing interest in the present work.

The junior author would acknowledge especially the kindnesses and encouragement shown to him by Drs. E. R. Dunn and A. H. Wright. E. B. Chamberlin, of the Charleston Museum, has generously loaned specimens in his care.

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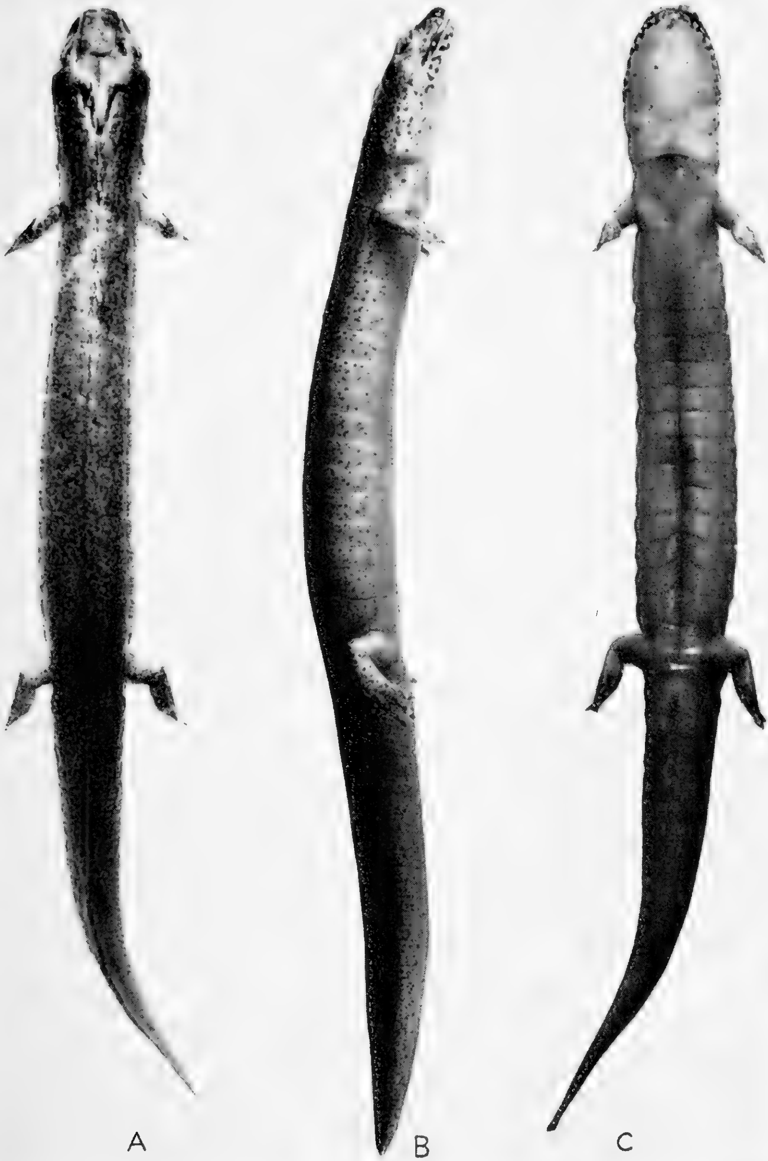

GYRINOPHILUS DUNNI, SP. NOV.

Type.—U.S.N.M. No. 113230 (Mittleman Coll. No. 382), female, Clemson College, Clemson, Pickens County, S. C., 700 feet. *A,* dorsal view; *B,* lateral view; *C,* ventral view. Actual length, snout to anus, 82.5 mm.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 101, NUMBER 3

ENVIRONMENT AND NATIVE SUBSISTENCE ECONOMIES IN THE CENTRAL GREAT PLAINS

(WITH FIVE PLATES)

BY
WALDO R. WEDEL
Assistant Curator, Division of Archeology
U. S. National Museum

(PUBLICATION 3639)

CITY OF WASHINGTON
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During the past 10 years an increasing interest has been manifested in the relations of man to environment in the Great Plains. Widespread droughts, spectacular dust storms, and recurrent crop failures are driving home again a fact which had been largely forgotten during the preceding prosperous decades—namely, that the climatic fluctuations to which the region is subject can be of sufficient magnitude to render man's occupation precarious. Numerous farms have been abandoned, and there is a rather general belief that much of the land is wholly unsuited to agriculture. Students of ecology and geography, recalling similar happenings in the past, have been insisting again that a long-range program of land utilization in place of the present haphazard methods would make possible the recovery of much of the supposedly worthless area.

It is not my intention here to suggest a cure for the economic problems arising from the conditions just noted, but rather to examine certain pertinent facts brought out by recent archeological investigations. We know now that long before white explorers ventured into the Great Plains, the region had been exploited in different ways by various native peoples. There is a growing belief that some of these aboriginal groups may have had to cope with adverse climatic conditions similar to those faced by man here today. The evidence is still fragmentary and scattered, because the area involved is enormous and the workers are few. Still, it may be worth while to indicate the directions in which the available data appear to lead.

For present purposes the central Great Plains comprise the area included in the States of Kansas and Nebraska. We shall review briefly the environmental setting as a background for an outline of the historic and prehistoric native subsistence economies. This will be followed by a consideration of the possible significance of certain inferred climatic variations upon past human populations.[1]

ENVIRONMENTAL FACTORS

To the casual observer traveling across Nebraska and Kansas along the main thoroughfares, the region exhibits a rather wearisome uniformity. In broadest outline it is a land of low relief, few trees, and little rainfall—of sun and wind and grass. A closer regard for the details of topography, native flora and fauna, and other aspects of the environment will show, however, that there are a number of natural variations (see Shelford, 1926, and Fenneman, 1928) which bear on man's utilization of the land.

The western portion of the area is a part of the High Plains province (fig. 1)—the remnant of a great outwash plain which in Tertiary times reached from the mountains into eastern Nebraska and Kansas. The High Plains are characterized by broad, monotonously flat upland areas which, toward the north, tend to become uneven or gently rolling. Rivers heading in the Rocky Mountains, such as the Arkansas and Platte, flow eastward across this belt in wide, flat-floored valleys. Lesser streams rising within the High Plains occupy shallow, open valleys which in places give way to picturesque rock-walled canyons. Where the secondary valleys have been cut through the unconsolidated Tertiary silts, sands, and gravels into the impervious underlying formations permanent springs occur. These give rise to perennial creeks flowing in verdant valleys which contrast strikingly with the surrounding uplands and which, since time immemorial, have provided ideal camp and village locations for primitive man (pl. 3). Where not under cultivation, the uplands are dominated by buffalo and grama grasses, with yucca, cactus, and sagebrush locally abundant. In the valleys there are groves of hackberry, cottonwood, and willow, with some elm and ash. Thickets of wild plum, elderberry, and other edible native plants are scattered along the ravines and stream valleys. Juniper grows along the valley rims, and in parts of Nebraska there are stands of western yellow pine. Native fauna included notably such animals as the bison, antelope, mule deer,

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[1] For helpful information and stimulating suggestions as this study developed, I am particularly indebted to Dr. C. E. Leighty, J. S. Cole, and O. R. Mathews, agronomists at the Division of Dry Land Agriculture, Bureau of Plant Industry, U. S. Department of Agriculture; and to Harry E. Weakly, junior agronomist at the North Platte Experimental Substation of the College of Agriculture, University of Nebraska.

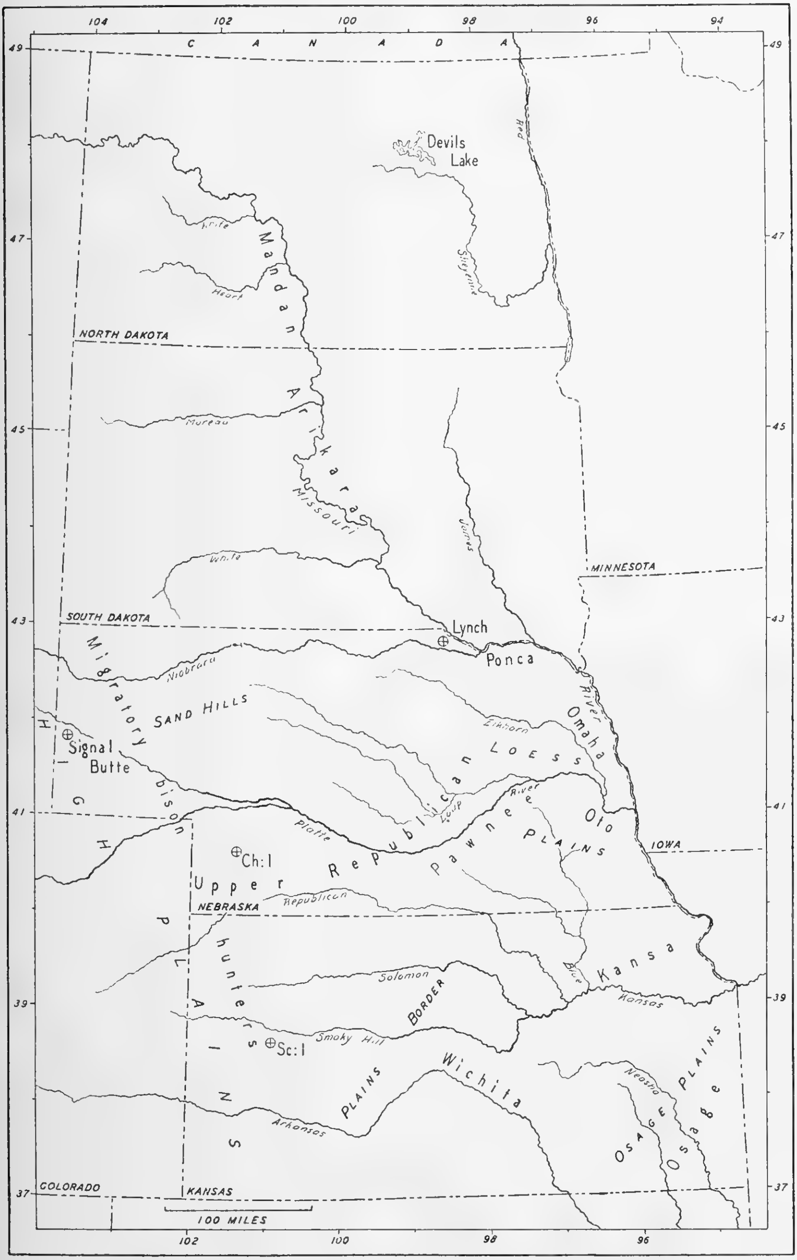

FIG. 1.—Map of the central Great Plains and upper Missouri Valley, showing physiographic divisions, tribal groups, and archeological sites considered in the present paper.

prairie dog, coyote, black-footed ferret, jack rabbit, badger, and smaller forms, and game birds such as prairie chicken and grouse.

East of the High Plains there is a marked change in the terrain. North of the Platte River in Nebraska are the Sandhills, a rough, hilly area dotted with ponds, lakes, marshes, and hay flats. The hills are in reality sand dunes which are held fast by a cover of bunchgrass interspersed with yucca and cactus. Trees are scarce except in the vicinity of ranch buildings. There are few streams, but those which head in the region, notably the several forks and upper tributaries of the Loup, carry an abundance of excellent water throughout the year. They head in shallow, grassy swales which soon give way to deep canyons lined with deciduous timber, plum thickets, and other vegetation.[2] Wild rice grew in some of the shallow lakes and was an important native food item (Gilmore, 1919, p. 67). Beaver, muskrat, deer, and smaller mammals inhabit the valleys; coyotes and jack rabbits abound; and great numbers of waterfowl still have their nesting grounds about the lake margins. Like the High Plains, the Sandhills are a region of low rainfall. Since the soil is loose and sandy and tends to blow readily when the sod is removed, large-scale agriculture is impracticable and cattle raising is the principal activity today.

South of the Republican River, in north-central Kansas, the eastern front of the High Plains has been dissected by stream erosion to produce the so-called Plains Border. This is a belt of high plateaus and prominent east-facing escarpments cut through by the deep, broad valleys of the Smoky Hill, Saline, Solomon, and their tributaries. Buttes and ridges are a conspicuous feature of the landscape. The fertile river valleys are fringed with forests of oak, elm, ash, walnut, cottonwood, and other hardwoods, and bluestem and bunchgrasses formerly clothed the upland areas. Native fauna included all the larger forms found on the High Plains together with numerous other species more typical of areas to the east.

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[2] In 1895 Bessey (1896) observed that relict stands of western yellow pine were to be found in the canyons along the Niobrara River as far east as Holt County, along the North Platte and Lodgepole Rivers to Lincoln County, in widely isolated canyons in Valley, Custer, Greeley, and other Counties in central Nebraska, and along the Republican to the vicinity of Franklin. These localities lie for the most part west of the 99th meridian. Hussong (1896) also calls attention to the fact that "yellow pine grew formerly in and along the canyons south of the Republican River in Franklin County . . ." Early settlers cut the larger trees for fuel and posts, and transplanted the smaller ones to gardens and lawns. Bessey held that these distributions were best explained "by supposing that the central region was once wholly or in part covered with forests."

East of the Sandhills and Plains Border provinces the Great Plains give way to what was formerly a bluestem and prairie-grass region. In eastern Nebraska the Loess Plains present a flat to rolling or hilly terrain. A thick mantle of loess extends from the Missouri Valley westward to the Sandhills and, as a narrower band, between the Platte and Republican Valleys to the High Plains in southwestern Nebraska (pl. 4, fig. 1). To the southeast it merges into the unglaciated gently rolling Osage Plains lying south of Kansas River. Throughout all this region, the streams run in broad, bluff-lined, often terraced, valleys. Fine stands of burr oak, elm, walnut, hickory, sycamore, and other hardwoods skirt the streams. Edible plants include the wild grape, plum, chokecherry, mulberry, and a number of tuber-bearing forms (see Gilmore, 1919). Other items which unquestionably figured in aboriginal economy were the Osage orange or bois d'arc, papaw, pecan, and persimmon, all found in eastern and southeastern Kansas. Bison, elk, antelope, and deer found unlimited pasturage in the valleys and on the deeply grassed uplands. Wolves, coyotes, badgers, and rabbits were plentiful; along the streams were beaver, bear, otter, raccoon, cougar, opossum, wildcat, fox squirrels, and a host of lesser forms. Most of these followed the wooded valleys westward far into the plains. Permanent streams are, or were, the rule, and fine springs formerly abounded on the larger as well as on many of the lesser watercourses. Precipitation, except in the west, is ample for agricultural needs, and the soils everywhere are deep, rich, and easily worked. Today this is the most densely populated and the finest agricultural land in the central Great Plains.

The Loess Plains are flanked by a narrow strip of rugged hills on the east where short, deeply incised creeks and narrow, heavily timbered ravines empty directly into the Missouri River. Broadleaf forests and dense thickets were formerly dominant, and the district abounded with game and other wild-food resources. Historical accounts indicate that the lofty bluffs fronting on the Missouri were bare of trees during the early nineteenth century, but the valleys must always have been well wooded.

From the standpoint of agriculture, whether modern or aboriginal, probably the most important factor in utilization of the Great Plains by man is climate (Kincer, 1923, and Climatic summary of the United States, sections 38-41). The region as a whole is characterized by warm summers with abundant sunshine; by winters that are cold and dry; and by considerable windiness throughout the year. In the central portion, as we have defined it, there is a frost-free growing season of 150-200 days, sufficient to mature most cereals and vegetable crops. Precipitation decreases markedly from an annual total of about 40 inches in southeastern Kansas to 15 or 18 inches in western Kansas and Nebraska. Because of the dry winters, the moisture stored in the soil is generally scanty; hence crops depend chiefly on the rainfall during the growing season. In this respect, the average annual precipitation shows a favorable distribution, since about 70 percent or more falls between April and September.

As Smith (1925, p. 413) has pointed out, "averages do not tell the whole story. Averages rarely happen. The freaks of the season decide man's chances . . ." In the Great Plains, the minimum precipitation required for successful agriculture by ordinary methods is somewhere between 15 and 20 inches annually. This means that over much of the region, particularly west of the 98th or 99th meridian, the yearly average is very close to the minimum required for successful crop growth, and hence that the year to year variation is of very great importance. A decrease in rainfall of only a few inches, particularly if continued for several years, may result in a major disaster for the grain farmer.[3] Furthermore, long-time weather records show that in the western Great Plains "there is less than the normal amount of rainfall in more than half the years." Farming except by specialized methods is rendered still more precarious by the fact that there may be several seasons of deficient moisture. These fluctuations are of variable duration, do not come in regular succession, and cannot be forecast with any accuracy.

The character of the summer rains must also be considered. In large part, they come as thunderstorms, often of great violence and short duration. Downpours of 3 to 6 inches within a 24-hour period have been recorded at many points, this sometimes exceeding in amount the normal precipitation for the month in which it occurs. The rains may come with such force that the ground surface is puddled, so that most of the water runs off before it can be absorbed

[3] The delicate balance between yearly rainfall and crop yields in this western area has been strikingly demonstrated by Cole (1938). From weather and crop records for 14 stations in western Nebraska, Wyoming, North and South Dakota, and Montana, he has determined the mean precipitation and mean average yield of spring wheat over periods varying in length from 10 to 28 years. With an average precipitation of just under 15 inches, the average wheat yield was slightly over 15 bushels per acre. When average precipitation fell 20 percent to 12 inches, wheat yield dropped nearly 50 percent to a trifle over 8 bushels. A further lowering of precipitation to 50 percent of normal thus resulted not in a half crop but in no crop at all. No comparable statistics are available on rainfall and corn growth in this region, but a similar correlation may be suspected.

by the soil. These storms, furthermore, are mostly local, with short, erratic courses that may leave one small area drenched while surrounding sections receive little or no moisture. Similar local differences are reflected in the annual precipitation records from time to time. Thus, in 1875 and again in 1901-3 inclusive at Dodge City, Kans., annual precipitation was from 50 to 90 percent of normal (average, 19.9 inches); but during the same years at Hays, 85 miles to the north, there was an excess of moisture ranging from 5 to nearly 50 percent (average, 21.28 inches).

Droughty conditions in summer are often attended by prolonged periods of high temperatures. Southerly winds predominate; being warm, they have a drying effect, and their high velocity favors rapid evaporation. Particularly destructive are the so-called "hot winds" which may accompany shade temperatures of 100° to 110°. They have been likened to a blast from a hot furnace, and frequently cause much damage to crops and serious discomfort to animal life. Immense havoc may be wrought in a few hours if these winds occur at critical stages of crop development, and when they continue for several days man and beast alike suffer intensely and widespread crop failures result. Many farmers insist that these hot winds can kill the corn crop even when through subirrigation or otherwise the soil is moist enough to meet the normal requirements of the growing plants. I am not certain, however, that this view has general acceptance among impartial observers.

HISTORIC SUBSISTENCE ECONOMIES

The 99th meridian, lying somewhat east of the line of 20-inch annual precipitation, may be regarded as the approximate dividing line between the Great Plains on the west and the true prairies or prairie plains on the east. It will serve also as the line of demarkation between two strikingly divergent native subsistence economies in the central Great Plains during the nineteenth century. To the east, where soil and especially climatic conditions are today recognized as most favorable for farming, the native economy was based on horticulture with hunting secondary. West of this line, where bitter experience has since shown the white settler that agriculture is likely to be a highly uncertain venture, hunting was of primary importance.

The principal natural game resources of the High Plains have already been noted. What they may have lacked in variety was more than offset by the abundance of certain species. During the nineteenth century the High Plains and the Plains Border immediately to the east were preeminently the range of the great bison herds. Parasitic on these were several Siouan, Algonquian, and Shoshonean Indian tribes whom we may term the migratory bison hunters (fig. 1). North of the Platte were the Dakota bands; farther south was the habitat of the Cheyenne, Arapaho, Comanche, and Kiowa. Throughout the spring, summer, and early fall organized bands of these Indians hung about the flanks of the herds, subsisting chiefly on the flesh of the bison and drying large quantities of meat for winter use. In winter the roving village units usually returned to certain sheltered spots which because of water, wood, and forage for horses were used year after year. Large herds of horses were to be seen at every camp. The portable skin tipi was universally used (pl. 1). Skin working was highly developed; otherwise, implements, utensils, and industries were limited to essentials which could be moved easily and conveniently on horseback from camp to camp. Surplus foods were stored in skin containers. Agriculture was nonexistent, as was the potter's art. The gathering of quantities of wild fruits, nuts, berries, and starchy roots and tubers supplemented the chase (Carlson and Jones, 1940); maize was obtained by trade or theft from settled horticultural tribes. An elaborate militaristic system had been built up, and much of the time not occupied in food getting was given over to warfare and horse stealing. These peoples recognized no definite tribal boundaries, and the distances traveled by them during their annual hunting trips and in raiding forays frequently totaled many hundreds of miles.

East of the 99th meridian, since the coming of the white man, have dwelt chiefly Siouan- and Caddoan-speaking tribes. Eastern Kansas was held by the Osage, northeastern Kansas by the Kansa, eastern Nebraska by the Oto, Missouri, Omaha, and Ponca. Farther to the west, on the Loup, Platte, and Republican Rivers, stood the villages of the Pawnee, a confederacy of Caddoan tribes whose nearest kindred linguistically were the Arikara in South Dakota. At the dawn of the contact period, the Wichita are believed to have had a group of settlements in central Kansas in the vicinity of the great bend of the Arkansas. These were abandoned during the eighteenth century for other lands farther south. The rest of the tribes enumerated remained in their respective locations until reservation days a century or so later.

All these tribes dwelt in large fixed villages situated near streams where wood, permanent water, and arable ground were to be had. Habitations were circular earth-covered or grass-thatched lodges (pl. 2). Subsistence was based primarily on the cultivation of maize, beans, and squash, to which were added a long list of wild berries, fruits, and tubers (Gilmore, 1913, and 1919). The latter included wild plum, hackberry, chokecherry, sand cherry, wild potato (*Ipomoea pandurata*), ground bean (*Apios tuberosa*), the pomme blanche (*Psoralea esculenta*), and others. Of considerable importance, too, especially after acquisition of the horse about 1700, were the products of the chase. Bison were the principal game animal, and to obtain them one or two well-organized hunting trips were made annually into the western plains. The Omaha and Ponca hunted north of the Platte into the Sandhills; the Pawnee went either up the Platte and Republican Valleys, or else shared with the Kansa and Osages the Plains Border and adjacent regions in central Kansas. At such times the entire population of the villages excepting the very young, the senile, and the decrepit moved en masse, dwelling in portable skin tipis and hauling their impedimenta on horseback or by travois, and living in general like the migratory bison hunters. At the temporarily deserted villages, the possessions which could not be carried along were concealed in underground pits. Under aboriginal conditions all these groups made pottery, and possessed in addition well-developed industries in stone, bone, horn, shell, and other materials. Whereas the temporary campsites of the migratory bison hunters today show little evidence of occupancy beyond hearth areas and possibly a few stone implements and animal bones, the abandoned house sites, cache pits, and accumulated refuse deposits of the village dwellers usually yield a rich harvest for the archeologist.

Fundamentally, the native agriculture of the Great Plains was of southeastern type, with tillage mostly or entirely by the hoe. The old type of hoe consisting of a bison shoulder blade lashed to a bent or forked stick survived until very late times, being used side by side with iron tools supplied by the traders. The fields—more accurately described as gardens—were small, ranging in size from ¼ to 3 or 4 acres. No attempt was made to break out the tough sod of the uplands. In the valley bottoms, the plantings were confined to little patches of loose alluvial soil scattered along the creek banks or lying at the mouth of a ravine. Because such spots were usually limited in number, the women often found it necessary to travel from 5 to 10 miles to and from their gardens. Corn, beans, and squash were the principal crops, but sunflowers, tobacco, and watermelons were also grown (Gilmore, 1913, p. 322). Women did all the planting and cultivating. Fertilizers were unknown and there is no evidence that irrigation was attempted. It is not definitely known whether the Indians of the central Great Plains had developed special deep-rooted, early-maturing, or droughtresistant varieties of corn, as had the Mandans of the upper Missouri (cf. Will, 1922), but it is quite possible that in the course of years some selection of this sort had taken place.

The fields were ordinarily hoed only once or twice. After the second hoeing, in June, the entire population of the village set out on the summer hunt, returning in September to harvest the crops. Surplus corn was boiled, cut from the cob, and dried, and then stored in underground caches. These caches, when emptied of foodstuffs or when rendered unfit for further use by spoilage of their contents, were abandoned, often to be refilled with refuse. Such pits are a common feature of every village site so far excavated in the central Great Plains where horticulture is evidenced. In the early historic villages of the Pawnee along the Loup and at the contemporary Wichita (?) sites in central Kansas, these caches are often 6 feet deep, and they have been known to attain a depth and a diameter of 10 feet or even more. At later sites, particularly in those dating after 1800, caches seldom reach these dimensions. It is not yet clear whether this decrease in size reflects smaller crops due to a slackening interest in farming and a correspondingly greater reliance on hunting or is attributable to some other factor.

The Pawnee and Omaha used an upright wooden mortar with pestle for grinding corn; their protohistoric contemporaries in central Kansas used the flat or hollowed stone mealing slab with muller.

ARCHEOLOGICAL CONSIDERATIONS

As systematic archeology adds perspective to our picture of native life in the central Great Plains, it becomes increasingly clear that the two fundamental economic patterns outlined above, or variants thereof, have long been present locally, but that man's emphasis has shifted back and forth from one to the other. As Kroeber (1939, pp. 76-79) has indicated, ". . . the historic Plains [horse] culture was a late high-pressure center of culture in a region which previously had been rather conspicuously low-pressure." He is undoubtedly correct, too, when he observes further that in the prehistoric period, prior to the sixteenth century, the plains were a cultural margin. By comparison with the eastern Woodlands and the Southeast, where advanced mound-building civilizations once flourished, the region west of the Missouri is characterized by antiquities of quite unspectacular nature. Temple mounds, for example, are nonexistent; and the practice of raising tumuli over the dead, which serves to emphasize the highly elaborated burial cults of the east, extends only a little way into the prairie plains of eastern Kansas and Nebraska and is not indicated at all for the plains proper.

The admittedly marginal nature of the semisedentary village cultures in historic times, together with the nomadic mode of life followed by the "typical" plains tribes farther west, has tended to obscure certain facts relating to the earlier agrarian peoples in the area. Kroeber (op. cit.) states that "It is scarcely contendable that the western plains were wholly uninhabited before the horse was available. Agricultural groups from east and west probably strayed in now and then and tried to farm. Small groups could make a living by combining bison and river bottom hunting with berry and root-gathering . . ." Archeology shows that primitive maize growers from the east had indeed penetrated far beyond the western margin of the prairie plains and had established themselves along many of the stream valleys in the High Plains. Their settlements were much smaller—and far more numerous—than those of such historic village tribes as the Pawnee. It is hardly accurate to speak of these prehistoric groups as mere "strays," for they came and spread in sufficiently leisurely fashion to scatter their remains along almost every arable stream valley with reasonably sure water as far west as the Colorado line. The diffuse nature of this early occupancy is in striking contrast to that of historic times when such tribes as the Pawnee dwelt in a very few large compactly built towns within a few miles of one another.[4]

Strong (1935) was the first to point out clearly that in the light of archeology the limitations of environment in the Great Plains were not so severe as many have been led to believe. In the long-range view, the droughts, excessive temperatures, and searing winds, which have played havoc with the present-day farmer and his commercial ventures, are comparatively transient if recurrent phenomena. Under normal climatic conditions the region is less hostile. Some degree of success, at least, must have attended the efforts of the native peoples who, content with a subsistence agriculture, ventured to try their hand at wresting a living from the soil of the short-grass plains.

As an example we may cite the recent discovery of pottery-bearing sites yielding definite proof of native farming activities in Chase

[4] The Pawnee after 1800 were variously credited with 5,000 to 12,000 persons. I suspect that if these were redistributed among the older sites, many of the latter would be decidedly underpopulated. Even granting that not all the small prehistoric sites were inhabited synchronously, I am of the opinion that there may at times have been about as many Indian farmers in prehistoric Nebraska as there were during the nineteenth century. A very considerable proportion of these, moreover, lived in the High Plains area.

County, Nebr. (see fig. 1, Ch: 1), and in Scott County, Kans. (fig. 1, Sc: 1).[5] These sites lie near the 101st meridian, 300 miles or more west of the Missouri, and well within the dry High Plains province (pl. 3). Both have yielded charred corn, together with bone hoes made from the scapula of the bison. At the Scott County site (pl. 3, fig. 1), where certain puebloan influences suggest the possibility of irrigation, the remains of squashes or gourds were also found. The great abundance of animal bones, as well as the very limited positive evidence of fixed habitations, leads to the belief that hunting probably ranked first in the food economy, with horticulture perhaps a side line. There is no reason to suppose that the inhabitants of these sites were related to the Pawnee or to any of the other Caddoan or Siouan village tribes of the eastern plains, or that they were directly ancestral to the Dakota, Cheyenne, and Arapaho who roamed the same area in the late eighteenth and nineteenth centuries. Scant amounts of iron trade materials indicate an early historic or protohistoric dating. The sites have been assigned to the Dismal River culture; it is possible that they will eventually be attributable to some of the semihorticultural Apache communities which according to seventeenth- and eighteenth-century Spanish documents formerly lived in the bison plains. At present they represent the westernmost points at which maize specimens have been reported archeologically in the central Great Plains.

In an earlier period, before any European influences had yet reached the area, horticultural peoples of another sort dominated the central Great Plains. Most widely distributed and best known are those who left the remains comprising the Upper Republican culture (Strong, 1935, pp. 69-124, 245-250, 275-278; Wedel, 1935, and 1940b, pp. 310-312; Champe, 1936). These remains occur throughout the Loess Plains to the edge of the Sandhills and south to the Smoky Hill-Kansas River drainage, with a westward extension far up the Republican (pl. 4, fig. 1) and Platte basins.[6] They consist of innumerable small village sites situated near former springs or other permanent water on the flood-free terraces which characteristically border many

[5] Wedel, 1940a; unpublished field notes by A. T. Hill, Lincoln, Nebr.

[6] It is interesting to note that in terms of present-day agricultural regions, the village sites of these prehistoric agrarian peoples are most plentiful in those portions of Nebraska and northern Kansas which are assigned to the Corn Belt (see O. E. Baker's map in Atlas of the Historical Geography of the United States, pl. 142A). Their range also includes adjacent districts in northern Kansas now given over to hard winter wheat. From surface finds of pottery, it appears that they may have inhabited the present corn-wheat zone in northeastern Colorado.

of the creek valleys. The villages included from a half dozen to two or three dozen rectangular pit houses scattered over several acres of ground. Unlike the historic Pawnee villages, these earlier communities were apparently unfortified. Cache pits are present in all these sites; they seldom exceed 3 or 4 feet in greatest depth and diameter, and thus average much smaller than those of the early historic Pawnee. In them are found charred maize, beans, animal bones, pottery, stone and bone artifacts, and other evidences of human industry. Universally present is the bone hoe. Charred corn, cobs, and beans have been found in these sites as far west as Medicine Creek in Frontier County, Nebr. Typical pottery, together with evidence of earth-lodge remains, occurs still farther west in Chase County, and excavation will probably show that the occupants of these villages also practiced farming. Inferentially, this must have been on a small scale and by methods closely similar to those described above for the Pawnee and their neighbors. The hoe, and also the crops evidenced through archeology, all have historic counterparts. Since the prehistoric villages were much smaller, it can be assumed that sufficient arable ground was available in the bottom lands close at hand. The horse was unknown, but since the villages were scattered widely over much of the choicest bison range it is probable that ample supplies of meat could be obtained by foot hunters whenever desired. At any rate, the bone refuse in their sites shows that the Upper Republican peoples relied probably more on the bison than on any other single species for meat.

A somewhat variant contemporaneous manifestation along the Missouri River bluffs has been termed the Nebraska culture. Here, too, are found rectangular earth lodges, cache pits, pottery, and other evidences of a settled horticultural mode of life. Animal bones indicate that white-tailed deer, elk, and smaller mammals figured much more heavily in the native diet than did the presumably more distant and less easily obtainable bison. In this respect the nonequestrian prehistoric inhabitants of the immediate valley of the Missouri differed from the historic Siouan tribes who, mounted, could and did travel hundreds of miles westward in quest of the bison.

Underlying the widespread Upper Republican and contemporaneous manifestations are other pottery-bearing horizons. Remains designated as Woodland are found in small obscurely situated sites which have so far received scant notice from archeologists. In the ravines of eastern Nebraska they occur as artifact-bearing occupational strata exposed in newly cut banks, with an overburden that varies from 6 to 25 feet or more (pl. 5, fig. 1). Farther west, as in the High Plains of Lane County, Kans., and elsewhere, similar strata are often overlain by wind-blown soils. It is still uncertain whether these overlying materials represent short cycles of abnormally heavy precipitation (in the east) or of excessively dry, windy conditions (in the west), or are due to slower but long-continued erosional processes. The extent to which the Woodland groups depended on cultivated crops is also a question since the sole evidences yet reported of horticulture—at the Walker Gilmore Site in Cass County, Nebr.—involve only the squash and gourd (Strong, 1935, p. 193).

Apparently contemporaneous with the Woodland sites are others along the Missouri in northeastern Kansas and nearby Missouri, which show a close similarity in several respects to the Hopewellian remains of the Mississippi-Ohio drainage. Evidence of horticulture is generally wanting throughout the Hopewellian horizon in the eastern United States, but it has been postulated that such an economic basis would have been necessary to so highly developed a civilization (Setzler, 1940, p. 262). At any rate, the only Hopewellian-like village site so far investigated seriously on the Missouri yielded direct proof of horticulture in the form of charred maize and beans (Wedel, 1938, p. 101). The bone hoe is absent, probably having been replaced by implements of stone or other material. To what extent the local economy was based on gardening is not clear, but cache pits possibly for storage of domestic crops were relatively plentiful. These yielded considerable quantities of deer and raccoon bones, but almost none of the bison. Since this complex does not appear to have penetrated very far west beyond the Missouri it is of minor interest so far as primitive horticulture in the Great Plains is concerned.

The prehistoric potters and farmers of the central Great Plains are thought to have moved into the region from a general easterly direction. If the Woodland peoples practiced horticulture, as we know the later Upper Republican groups did, then at least two principal waves of immigration by native farming economies are indicated. How long the interval separating these two is we do not know; there is no clear proof that the Upper Republican developed directly out of the Woodland, though some contact between the two is indicated (cf. Wedel, 1940b, p. 346). Both groups spread westward into the High Plains, nearly or quite to the present Colorado line. There is no way of telling whether either found the western plains uninhabited. It is abundantly clear that hunting economies had occupied much of the region at a far earlier time, as shown by the presence of Folsom, Yuma, and other ancient nonagricultural remains. Since hunting tribes again controlled the area in historic times, it can be inferred that occupation by native subsistence economies based on maize constituted a relatively brief interlude which was preceded and followed by very much longer periods of occupancy by nomadic or seminomadic bison hunters.

The first Spanish explorers to visit the western plains in the sixteenth century found them occupied by nomadic Indians who had "no other settlement or location than comes from traveling around with the cows." In terms of modern linguistic groups, these are thought to have been Athabascans, probably Apache or Lipanan (Harrington, 1940, p. 510). Just when they arrived is not clear, but by 1541 the little farming communities over most of the Upper Republican area had evidently been given up. At any rate, there is no mention in the narratives of the Coronado or subsequent expeditions of anything corresponding to the Upper Republican village sites as these have been defined by archeology. The first permanent settlements seen by the sixteenth-century Spaniards in what is now central Kansas were large, some of them estimated to number 200 houses (Winship, 1896). The houses were of straw, and the natives are described as having corn, beans, and melons. All of this is reminiscent of the large protohistoric villages found in Rice and McPherson Counties, Kans. Insofar as it concerns fixed villages of horticultural peoples it also calls to mind the great fortified towns of the protohistoric Pawnee on the Loup River in Nebraska—possibly the Harahey of Coronado's chronicles (see Lesser and Weltfish, 1932, p. 12). Farther west, according to these explorers, were only migratory hunters whose mode of life was essentially the same as that of the historic hunters except for innovations taken over by the latter from white men. The cause or causes for the observed abandonment of the western plains by native farming peoples in late prehistoric times is one of the problems now confronting plains archeologists.

DROUGHTS AND PREHISTORY

Van Royen (1937, p. 637) has remarked that "there is little doubt in the minds of students of weather and climate that wide borderland areas between humid and arid regions will always be subject to recurrent droughts of varying duration and intensity, such as those experienced in historical times. Also, before the dawn of recorded history droughts occurred, some of which were brief, others evidently very long." The Great Plains constitute just such a borderland zone, with arid regions on the west and southwest and humid regions to the east. We may turn, therefore, to a consideration of certain phenomena which suggest drought conditions during the prehistoric occupancy of the central Great Plains, keeping in mind particularly their possible effects on the native horticultural peoples.

Two sites in Nebraska are of especial interest in this respect. They are Signal Butte in the North Platte Valley near the Wyoming line, and the Lynch Site on lower Ponca Creek in Boyd County about 12 miles from the South Dakota border. Archeological remains at Signal Butte and their geologic context have already been detailed elsewhere (Strong, 1935, p. 224-239). Briefly, they consist of three prehistoric levels of human occupancy separated from one another by layers of wind-deposited loess from 18 to 24 inches thick. The topmost cultural horizon includes pottery of Upper Republican and Dismal River types, and may be no more than 300 to 500 years old. The middle and lower strata, yielding no pottery, are believed to represent much older hunting cultures. The occupational strata consist in part of humus, and presumably indicate periods of increased humidity. The intervening sterile layers are attributed to dry, windy periods. Van Royen suggests that "one or both of the sterile strata on Signal Butte may correspond to a long dry period from three to four thousand years ago or that they may be even older." Strong's estimate is more generous, with 8,000 to 10,000 years given as the possible time which has elapsed since level I (the lowest) was inhabited.

At Lynch (Van Royen, 1937, p. 638), the archeological remains cover a considerable area on the bluffs just north of Ponca Creek. As revealed in excavations by the University of Nebraska, their most striking feature is the presence of "a thick dark stratum, which near the ends of the [University test] trenches was found to lie about a foot beneath the surface and which was covered near the center by eight feet of sand. . . ." These sands, according to Van Royen, are wind-deposited, and were derived from the water-laid Pleistocene sands on the high terrace north and northwest of the areas of accumulation. The topsoil to a depth of 12 to 18 inches has been colored gray by plant matter and still supports a fair stand of grass. Wind activity here today is not great enough to produce dunes or sand drifts except where the grass cover has been killed off by cultivation or by overgrazing. The gray topsoil is too deep to be accounted for by the few decades which have elapsed since introduction of the plow in the district, and "since the culture stratum does not show any influence of the white man" it is suggested that the period of pronounced sand movement antedates the coming of Europeans. The observed conditions would imply a prolonged period of lower rainfall and destruction of the grasses, followed by increased wind action on the denuded ground surface.

The question of dating even approximately the Indian occupation at Lynch, and through this the drought which must have followed it closely, hinges very largely on accurate identification of the archeological materials in the dark stratum. A detailed report on these has not yet appeared, but certain generalizations can be ventured on the basis of sherds collected on the surface during several visits I made before and at the time of the excavations (Wedel, 1940b, p. 317; see also Van Royen, 1937, p. 647). The sandy overburden has blown extensively wherever modern cultivation is under way, this being especially true on fields a few hundred yards east of the diggings. On the denuded village surface there were abundant remains, and hearths could be found only a few inches below the plowed topsoil. A collection of several hundred potsherds including numerous rim pieces, as well as many end scrapers, projectile points, and other chipped forms indicated an interesting mixture of types. One group of sherds exhibited features characteristic of the Upper Republican horizon; others, including a few rim pieces with handles, were reminiscent of Nebraska culture remains. A third group, in which shell tempering was noted, included incised or trailed decoration, rims, and handles resembling in most particulars the Oneota wares of the upper Mississippi and Missouri Valleys. A few sherds bore parallel ridges on their exterior surfaces, apparently produced by the same paddling technique used so widely by the Pawnee, Mandan, Arikara, and other tribes in protohistoric and historic times.

The Upper Republican and Nebraska culture manifestations throughout the central Great Plains have been extensively worked, and in no case has iron, glass, or other evidence of contact with white men been noted. On the other hand, Oneota village sites in Iowa, Missouri, and Kansas have yielded small amounts of such material. All the available evidence indicates that in the Missouri Valley and westward, the Oneota remains are late. Some of the sites may antedate slightly the arrival locally of white men, but the strikingly uniform character of the remains over most of the area occupied would indicate that they were not spread over a very long period of time.

It is not clear whether all the several pottery types noted at Lynch occur together or whether there was a stratified succession of wares. It is possible that a late phase of the Upper Republican survived here for a time alongside an unclassified peripheral variant of the Oneota manifestation. In any case, the fact that pottery with definite Oneota affinities underlies the sand deposits is strong evidence that the latter were laid down within the last three to five centuries.

Much less striking than the sand accumulations at the Lynch site or the stratified remains at Signal Butte is the occurrence at many sites in the central Great Plains of a soil cover equally suggestive of dry, windy conditions. In a great many localities soil profiles have been partially obliterated by modern agricultural activities, but here and there in stream terraces can still be seen evidences of a dark humus zone buried under 10 to 30 inches of fine light-gray loess, without doubt wind-laid. That this old humus zone was at one time an inhabited surface is indicated by archeological observations. In the Republican drainage of southern Nebraska, as for example, on Medicine and Lost Creeks, Upper Republican pit-house sites have been found excavated into the humus line, with potsherds, bones, and similar village refuse littering the same level (Wedel, 1934, pp. 149, 152, 154; Strong, 1935, p. 76). That these houses were not dug from the present surface is shown by the presence of culturally sterile wind-blown materials which extend evenly and uninterruptedly across the old house basins and over the adjoining detritus-strewn humus zone. The present surface of this soil cover is usually flat with no suggestion of dunes or drifts. The material itself is finer than that at Lynch, and superficially resembles rather closely the sterile layers separating culture horizons at Signal Butte.

Upper Republican village sites blanketed in this fashion occur throughout the Republican River basin in southern Nebraska from Frontier, or possibly Hayes, County eastward at least to Webster County. I have observed a similar though thinner unbroken covering on Upper Republican sites in the lower valley of the North Loup River (pl. 4, fig. 2). Since widely scattered sites are thus involved the factors responsible must have been of more than local magnitude. At the same time, it must be pointed out that other Upper Republican sites in the Loup drainage are marked by shallow surface depressions, indicating either that less soil was deposited over them or else that the houses and caches were dug through the covering material and are thus later. The villages occupied by the Pawnee on the lower Loup and Platte Rivers seem never to have been thus buried, and the old lodge circles were always clearly visible before their obliteration by the plow. Still farther east, along the Missouri, the Nebraska culture sites which are believed to have been occupied synchronously with some of the Upper Republican villages, characteristically show deep, well-marked house pits where they are not under cultivation.

It has already been noted that Woodland sherds and stone artifacts have been found in western Kansas and in Nebraska in similar buried humus strata. Wherever Upper Republican and Woodland remains occur on the same location, the latter are always at the bottom. For example, near Healy, in Lane County, Kans., Upper Republican village remains (pl. 5, fig. 2, stratum A) occur just below the wind-eroded surface of several small terraces. Below, and separated by a few inches to nearly 2 feet of sterile gray soil (pl. 5, fig. 2, stratum D), is a dark-gray stratum yielding hearths and Woodland artifacts (pl. 5, fig. 2, stratum B).[7] The number of known similar occurrences in the Republican, Loup, and other more northerly river valleys is increasing.

Insofar as they relate to prehistoric man, the dust deposits of the Republican Valley and adjacent areas, as just described, have not been closely studied by physiographers or geologists. It should be noted that the repeated dust storms of the past decade accompanying droughts which wiped out the corn crop in many localities have not produced comparable formations in the Republican and Loup Valleys, though elsewhere deep drifts and dunes have been formed where fences, hedges, and other obstructions tend to break the wind. It is not certain that these deposits result from a single short, intense drought such as that evidenced at Lynch. It has been suggested to me that they can more reasonably be interpreted as a gradual accumulation over a period of many years. At the same time, the fact that the dust covers a dark humus stratum which often contains archeological remains would seem to indicate that a period of fairly rapid deposition followed a more humid interval which lasted long enough to produce a vegetative cover and to become the home of sedentary farming peoples. In other words, I see no reason why the different strata cannot be viewed as evidence of climatic fluctuations analogous to those inferred from the findings at Signal Butte.

Carefully controlled studies in the past decade have made it possible to arrange the major archeological horizons of the central Great Plains in sequential order (see summary in Wedel, 1940b). Where evidences of severe drought, or of prolonged periods of subnormal precipitation and consequent increased soil deposition, are definitely linked with these horizons it may be possible to determine the ap-

[7] What is possibly a third occupation zone here is indicated as stratum C in plate 5, figure 2; from it came only broken animal bones and fire-cracked stones, hence the horizon remains unidentified.

proximate time involved. At Signal Butte, as already indicated, the dry periods have been tentatively assigned an antiquity of several millenia. At Lynch, on the other hand, the archeological evidence points toward a very much more recent drought—one that might have occurred as late as the sixteenth or seventeenth century.[8] The dust blanket on the Upper Republican sites in southern Nebraska must have begun to accumulate at least 400 years ago, since there is evidence that the Pawnee were living in large villages in eastern Nebraska in Coronado's time (1541) but none whatever that contemporary horticultural earth-lodge-using peoples lived in the western plains.

The estimates of age here given are inferential, and rest on archeological and historical data. At present they cannot be checked by precise methods such as dendrochronology offers in the Southwest. However, as already indicated, red cedar (*Juniperus virginiana*) is widely distributed throughout the High Plains, and there is good evidence that western yellow pine grew scatteringly eastward to the 99th meridian as late as the nineteenth century. Moreover, it should be borne in mind that charred pine and juniper have been found in

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[8] M. E. Kirby, of the U. S. Engineers office at Omaha, Nebr., has called my attention to relevant data by Upham (1895, p. 594) concerning fluctuations in the surface levels of certain glacial lakes in North Dakota. Devils Lake and nearby Stump Lake in the northeastern part of the State present highly irregular outlines and are believed to occupy the valley of a preglacial river which has been elsewhere buried with drift. In historic times Devils Lake reached its highest level about 1830. At about the same time occurred record high-water levels in Red River and in the Great Lakes. Thus, 1830 would appear to represent the high stage in a period of heavy precipitation. The shore line of Devils Lake at that time is indicated by a line of heavy timber. Between this and the recent shore line Upham noted a stand of smaller trees which in 1889 showed a maximum of 57 annual growth rings. During the 1830 high stage the waters flowed into Stump Lake a few miles to the southeast, but the latter never attained the same level as Devils Lake owing to evaporation. The early postglacial outlet of Stump Lake into the Sheyenne River was dry during the 1830 high water, as shown by a stand of large timber growing across the channel. This timber corresponds to that marking the 1830 water line in Devils Lake.

At present, in the bed of Stump Lake, North and South Washington Lakes, and Lake Coe, all situated near Devils Lake, there are old stumps of trees which grew when the lakes were dry some time before the 1830 rise. Many of these have been uprooted and used for fuel. Some of the stumps on the lake bed showed as many as 115 annual rings, indicating well over a century of deficient rainfall. It is not known just when the protracted period of desiccation here indicated came to an end, but it must have been long before 1830, since many years of heavy rainfall would be required to refill the lakes. Upham suggests that the drought represented here may have coincided with the arid conditions in the Great Basin which are supposed to have dried up Pyramid, Winnemucca, and other lakes in Nevada about 300 years ago.

Upper Republican pit houses (Wedel, 1935, p. 170); that the former distribution of pine and the present occurrence of juniper overlap the known range of the prehistoric Upper Republican horizon; and that much of the area of overlap in the western plains has a low rainfall which is apparently directly reflected in tree growth. Working on wood specimens from historic log structures and from old stumps in gully fills in Lincoln County, Nebr., Weakly (1940) reports a continuous tree-ring sequence reaching back to about A. D. 1480. The buried material is said to have given "very readable ring sequences," but absolute dates have not yet been assigned. All this raises the hope that continued research, combining dendrochronology with archeology, will soon produce exact tree-ring datings for some of the late prehistoric and protohistoric culture horizons in the western plains, and also establish the time of some of the associated drought evidences in the same region.

In another paper (Wedel, 1940b, p. 329), I have suggested the possibility that abandonment of the western plains by sedentary horticultural peoples in late prehistoric times may have been due in part to inability to cope with drought conditions. This view has been questioned by ecologists with whom I have discussed the point. Their contention is that the small gardens of the Indians, unlike the present-day farms, would have been situated only in sheltered bottom-land pockets where there was maximum protection against hot winds and where natural drainage conditions would have provided subirrigation. Moreover, the practice of storing one to several years' supply of corn against the contingency of crop failure would have carried them through droughts such as those of the historic period. In this connection a perusal of the reports of the various Indian agents in the Kansas and Nebraska territories is instructive.

The effects of the droughts of 1860, 1870, and 1893-96, in terms of large-scale populational movements out of the plains by white settlers, have been frequently recounted.[9] Their effects on the native and transplanted Indian populations, however, seem to have gotten little attention. According to the report of the Commissioner of Indian Affairs for 1860, the Pawnee (pp. 94-95) "had about 800 acres of corn, pumpkins, beans, etc.; but owing to the extreme drought in this section of the country, and improvident farming, their crop is very light." Among the Oto and Missouri (ibid., pp. 96, 97) a highly favorable spring was followed by three rainless months, with "a constant burning sun and scorching wind, the result of which is the

[9] Summarized in Clements and Chaney, 1937, p. 41.

entire loss of their crops. . . ." Even the grass was burned up, so that neither the Indians nor the agency were able to lay up their usual reserve of hay for the winter. Along the Nemaha, the Sac and Fox (ibid., p. 99) fared a little better, with the prospect of half a corn crop and considerable hay. The Kickapoo (ibid., p. 101) in northeastern Kansas who had just been presented with oxen, plows, and other farm machinery, were giving up their farms consisting of "8 to 10 acres of soft turfless ground among the girdled trees skirting the narrow borders of the creeks" and were venturing out into the prairies. For them, 1860 brought the worst drought of their 30-year sojourn west of the Missouri, and a complete crop failure. The Pottawotamie (ibid., p. 41), the Sac, Fox, and Ottawa (ibid., p. 111), the Kansa (ibid., p. 113) together with the Kaskaskia, Peoria, and other tribes on the Osage River in eastern Kansas were equally hard hit. Total or partial crop failures are also reported for the Choctaw, Cherokee, Chickasaw, Quapaw, and Wichita (ibid., pp. 114-123) far to the south in the Indian Territory. According to the agents, the alternatives confronting the natives everywhere throughout this vast region were starvation, government aid, or recourse to the plundering of such of their white neighbors as were receiving relief from the government or from friends in the east.

A decade later, in 1870, drought struck again, but this time it affected the Indians over a much smaller area. At the Whetstone Agency, Dakota Territory, the crops were destroyed by a 2-month drought in June and July. At the Santee Agency, in northeastern Nebraska, 370 acres of corn were a total loss. The agent for the Ponca wrote that "Had it not been for the very long and severe drought, they would have realized a yield of at least 14,000 bushels. On the first of July their crops looked well, and I was of the opinion that the bottom lands would not be affected by the drought; on the contrary, the whole was an entire failure. . . . This tribe is now bordering on starvation." In southern Nebraska, of the Oto it is said that "On the bottom lands a few will probably succeed in harvesting light crops of corn; but I fear those . . . on the upland . . . will experience an almost entire failure of their crops. . . ." Throughout northeastern Kansas the tribes generally seem to have fared very well. Weather records show that Leavenworth, Kans., enjoyed an excess precipitation of nearly 25 percent in 1870, which suggests that the reservation Indians hereabouts may have been out of the main drought area.[10]

[10] References to insect pests are rare in these reports. In 1870, however, the agent for the Yancton Sioux suggested (p. 212) the advisability of removing

Prior to 1860, data on drought conditions in the central Great Plains are scarce. We may note, however, that in 1848 the Council Bluffs Agency reported that "The government has purchased the past season for the Pawnees between 1700 and 1800 bushels of corn, to keep them from suffering. . . . They are still in a miserable condition; their crops this season have almost been an entire failure, owing to the drought. Their corn in the Platte bottoms was literally burned up; . . . they will suffer, unless they make an unusual good hunt this winter."

The distressing conditions set forth in these reports are a significant commentary on the reactions of Plains Indian farming communities to drought. It can be objected that at this late date the old cultural patterns of such tribes as the Pawnee, Omaha, Oto, and Ponca were swiftly falling apart. Their horticultural economy was only a part-time interest, and probably but a dim reflection of what it evidently had been a hundred or two hundred years before. Moreover, tribes like the Kickapoo, Sac, Fox, Ottawa, and others, were originally residents of more easterly drought-free areas who had been moved onto reservations west of the Missouri so recently that there was insufficient time or incentive to make the necessary adjustments to a changed environment. All this is true. But it is also true that the area inhabited at this time represents the best corn-growing section in the central Great Plains, climatically and otherwise. It must be remembered, too, that there was no contemporary Indian agriculture beyond the 99th meridian in the High Plains, and the above observations contain about the only extant data concerning such activity under pronounced drought conditions beyond the Missouri.

The recorded droughts of the nineteenth century, despite their occasionally calamitous effects, were relatively short-lived affairs. Most of them meant only a year or two of subnormal precipitation; in no case has there been, since the coming of white settlers, as much as a decade of continuous drought and unbroken crop failure. For this reason, it is impossible to say how long or how intense a period of drought would be needed to kill off the sod cover to the point where large-scale soil movements could take place. Clements (1938, p. 202) states that "even a thin cover of vegetation controls the wind so

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these Indians from "a climate where crops are so uncertain, owing to the scarcity of rain and the ravages of the grasshopper. . . ." He says further that " . . . in five years of the last ten the crops were totally destroyed by the drought and grasshopper, and in one year of the ten there was about half a crop . . ."

effectively that soil-drift and deposition during the past must have been limited to bare areas such as ocean-strands and river-banks. During the historical period, dust storms have come only from soils exposed by man in the course of settlement." The second statement, at least, may need revision, since terrific sand and dust storms apparently rivaling in intensity those of recent years were experienced by McCoy and his surveying party in northern Kansas 200 miles west of the Missouri as early as 1830 (McCoy, 1840, pp. 408-409). The material which overlies Upper Republican sites can hardly have been due to man's work, since it unquestionably antedates the era of modern agriculture and could never have been an aftermath of the small-scale horticulture practiced by the people whose remains it covers.

In his discussion of the Lynch site, Van Royen (1937, pp. 645, 648) expresses doubt that 20 to 25 years of drought would have been sufficient to destroy the local sod cover and inaugurate wind erosion leading to the topographic changes there noted. On the other hand, many farmers in the western plains maintain that 5 years may be enough to kill the grass and start serious soil movements, even where no overgrazing has taken place. On this point, agricultural experts with whom I have talked corroborate the observations of the farmers. In light of these latter statements it would be interesting to know just how long the droughts suggested by the archeological record may have lasted. A possible clue lies in the tree-ring studies already mentioned.

Weakly (1940) has called attention to the presence of aeolian deposits in canyons in the vicinity of North Platte, Nebr., beneath which red-cedar stumps are buried. Annual rings on these stumps "indicate a period of over 30 years with deficient moisture. Apparently this drought period contributed very largely to the death of these trees." Presumably, the fill overlying these stumps is a result of wind action on the surrounding uplands after these had been partially or largely denuded of their sod cover. The drought conditions manifested here have not yet been dated. They have significant implications, however, for they suggest that prolonged droughts comparable to those held responsible for extensive ethnic disturbances in the Southwest in 1276-1299, and again in 1573-1593 (Douglass, 1935, p. 48), might well have occurred in the Great Plains, though not necessarily concurrent.

In addition to this as yet undated major drought, Weakly believes his tree-ring data prove the occurrence of a number of shorter periods of deficient rainfall. Some of these "would have been very severe even on the present population of this section and . . . would have been a major catastrophe to a population of aboriginal farmers. Several of the drouths were of sufficient severity to very largely depopulate the plains even now. . . ." (Letter of March 7, 1941.) In this same letter, Weakly informs me that the major dated drought periods previous to 1700 are as follows:[11] 1439-54 (15 years), 1459-68 (9 years), 1539-64 (26 years), 1587-1605 (except for 1594-96). I am inclined to suspect that if Weakly's chronology has been extended beyond question to the early part of the fifteenth century, he may be on the threshold of an exact dating for some of the Upper Republican village sites in western Nebraska.

We have already indicated that the western portions of the Upper Republican habitat have a low irregular rainfall which borders on the minimum required for successful farming. It can be assumed that these peoples farmed intensively and that they were far-sighted enough to lay by seed corn and food against a year or two of crop shortage. At the same time it may be doubted that their harvests were ever on the scale of those normally enjoyed by the later Pawnee and other horticultural peoples farther east. In light of the difficulties experienced by Indians in the eastern plains during the brief droughts of 1860 and 1870, I am led to believe that when hot, searing winds and droughty summers visited the aboriginal farmers throughout the western Great Plains, crop failures and some measure of destitution were their lot in prehistoric days as well. Dry years may also have given rise to insect plagues, as they do today, further complicating the native economy. The delicate balance between annual precipitation and crop yield has been noted elsewhere in this paper. If drought conditions recurred for several successive years, or if there was a drop of several inches in the average annual precipitation over a period of 10 or 20 years or more, perhaps with springs and watercourses drying up, there would have been no choice for the natives other than that of abandoning their villages and removing eastward to better-watered and more dependable regions. A sedentary mode of life such as that indicated for the Upper Republican peoples, involving relatively permanent earth-lodge villages, would have been impossible when climatic or other factors prevented the cultivation of maize. All this leads me to suggest again that the early horticultural peoples of the Upper Republican communities may have been forced out of their habitat in western Kansas and Nebraska, probably toward the east, in large part by a long-continued

[11] A manuscript detailing the results of Mr. Weakly's tree-ring studies is awaiting publication by the U. S. Department of Agriculture.

period of subnormal rainfall, the outstanding physiographic aftermath of which is seen in the dust which today covers many of their ancient living sites.[12]

[12] The relation between the prehistoric Upper Republican peoples and the historic Pawnee is still a puzzle. There is nothing in Pawnee traditions to suggest that this group was a late arrival west of the Missouri, and it is generally believed that they were firmly established in or very near their historic locale at the time of Coronado's march into the plains. Strong (1935, p. 277) has suggested that the Pawnee may have been the lineal descendants of the Upper Republican peoples. This is based on a number of resemblances involving basic house types, pottery, and the general semisedentary horticultural mode of life. Persistent search has so far failed to produce a single site in Nebraska which could be regarded as intermediate between the Upper Republican horizon and the earliest protohistoric village remains attributable to the Pawnee. On the contrary, the small, open, undefended villages, prevailingly rectangular pit houses, cord-roughened pottery, and communal ossuary burials of the Upper Republican peoples are consistently in contrast to the large, defensively situated, fortified towns, invariably circular earth lodges, corrugated paddle pottery, and individual flesh interments of the Pawnee. The much sought "clear unbroken line of ceramic and other development" foreseen by Strong is not yet at hand, nor can we say how long the gap in the proposed sequence is. The data on physical anthropology, which may well be crucial in this connection, are either nonexistent or unpublished.

Recent excavations (Wedel, 1941) in Rice County, Kans., have shown that small but consistent amounts of Upper Republican-like cord-roughened pottery occur here, along with puebloan sherds of ca. 1525-1650, at village sites tentatively ascribed to the Wichita. There is also some evidence of ossuary burial. Strong (1940, p. 382) has recently proposed that the Arzberger site near Pierre, S. Dak., represents "a late prehistoric horizon, basically Upper Republican, but in process of development into the more specialized and later protohistoric Pawnee (to the south) and Arikara (in the north)." As I have indicated in this paper, there is also a strong possibility that a late phase of the Upper Republican culture survived into virtually protohistoric times in northeastern Nebraska, as shown by the pottery remains at Lynch. In other words, traits which may be regarded as of Upper Republican derivation appear to have survived later in the eastern plains and in South Dakota and Kansas than in the Upper Republican-Pawnee region in Nebraska. One wonders, therefore, whether the postulated development from a prehistoric into a historic entity, or entities, may not have taken place outside the Nebraska area, with the Pawnee on the Loup and Platte Rivers representing a backwash. According to their traditions, the Pawnee entered Nebraska from the east and south rather than from the north, which might explain certain ceramic (as for example, the cloistered rims) and other elements in their material culture which have an easterly rather than Upper Republican flavor. This is admittedly a thorny problem and one which cannot be certainly answered with the information now at hand. As a working hypothesis, however, it may be well to bear in mind the possibility that the threads running from the Upper Republican to the Pawnee, if they exist, may have to be traced out of Nebraska and then back at a somewhat later period, which, in any case, should precede 1541.

As has been pointed out elsewhere, the occurrence of dust-covered humus strata containing human debris is more frequent in the central Great Plains than has commonly been supposed. Moreover, to the best of my knowledge this does not involve the remains of such historic tribes as the Pawnee and their Siouan contemporaries whose villages and campsites seem always to have been situated on the present ground surface. If the similarity between Signal Butte and other later stratified or "buried" sites can be taken as evidence of like climatic fluctuations, then it would appear that the record of man's activities in the western plains is linked with the periodic development of stable humus zones between which there are dry-weather dust deposits. Thus, in the archeological record we have Signal Butte I and Signal Butte II, each succeeded by periods of undetermined duration during which dust was being laid down. Later came pottery-making groups: First the Woodland, then the patently horticultural Upper Republican, each followed by periods of increased deposition. There is at present no way of determining accurately the length of time required for the development of these now-buried humus zones on which prehistoric farming peoples once carried on their everyday activities over much of the central and western Great Plains. It seems to me, however, that these intervals must have been of some length since the human occupancy spread westward about as far as climatic factors would permit corn growing. In any event, if the repeated interludes of deposition were indeed the aftermath of decreasing rainfall and increasing wind activity, as contrasted to the more humid periods which produced the humus layers, we may visualize the farming Indians as having ventured far out into the Great Plains during favorable times only to withdraw when droughts set in.

CONCLUSION

It need not be assumed from the findings of archeology that any major climatic change or permanent desiccation has taken place in the central Great Plains within the span of time represented by the various aboriginal pottery-making groups formerly resident there—or, as a guess, within the past 8 or 10 centuries. In all likelihood, however, shorter or longer periods of deficient rainfall have occurred repeatedly in prehistoric as in historic times. Some of these periods were probably of sufficient duration or intensity to depopulate the western plains for a time. The occupation of the region by migratory hunters since at least 1541 may well be due to the accidents of history as much as to any unfavorable climatic trends. That is to say, it is conceivable that had the hunters first seen by Coronado's party not received horses and firearms from the whites, maize-growing peoples might again have extended their occupation westward beyond the 99th meridian. In view of the still sketchy nature of our information on plains prehistory, it is impossible at this time to evaluate fully the respective importance of environment and of historical accident on the alignment of native economies in the region. Nevertheless, it begins to look as though alternate settlement and abandonment was true of primitive man's occupation of the western plains just as it has characterized the subsequent white man's tenure where large-scale government aid was not forthcoming during periods of adverse climatic conditions.

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TYPICAL SCENE IN A PLAINS INDIAN HUNTING CAMP OF THE NINETEENTH CENTURY

Photograph by S. J. Morrow, probably made in the upper Missouri Valley about 1870.

EARTH-LODGE VILLAGE OF THE PAWNEE, A TYPICAL SEMIHORTICULTURAL TRIBE OF THE EASTERN PLAINS, ON THE LOUP RIVER, NEAR GENOA, NEBR.

Photograph by W. H. Jackson, 1871.

1. BEAVER CREEK VALLEY IN SCOTT COUNTY, KANS.

The even skyline, scattered trees, and short grass are characteristic of the High Plains. A Pueblo ruin and other protohistoric Indian remains lie at the center of the view.

2. VIEW IN THE VALLEY OF STINKING WATER CREEK, CHASE COUNTY, NEBR.

The remains of a protohistoric village of hunting and farming Indians occupy the flat immediately across the stream.

1. VIEW IN THE REPUBLICAN VALLEY, FRANKLIN COUNTY, NEBR.

The Dooley site, type station for the prehistoric Upper Republican culture, lies on Lost Creek, just to the left of the loess bluffs.

2. STRATIFIED SITE ON DAVIS CREEK, NEAR COTESFIELD, NEBR.

Twelve-inch dust mantle (A) overlying dark gray humus stratum (B) containing potsherds and other remains of Upper Republican type.

1. DEEPLY BURIED HEARTHS AT WALKER GILMORE SITE (WOODLAND), CASS COUNTY, NEBR.

2. STRATIFIED SITE ON SALT CREEK, LANE COUNTY, KANS.

See page 19 for explanation.

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(With 11 Plates)

BY
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During the field seasons of 1931, 1932, and 1934-1937 extensive excavations were carried on by the writer and his various field parties, under the auspices of the Smithsonian Institution, in the pre-Russian sites of Kodiak Island and particularly in a remarkable old site on what became known as "Our Point," Uyak Bay. The chief object of these excavations was to recover the numerous skeletal remains buried in the deposits and thus obtain light on the nature of the old inhabitants of this anthropologically important region. As a result there were gathered several hundred skeletons or parts of skeletons which showed that long before the island was inhabited by the strain of people found there by the Russians and called by them the "Koniags," there was an extensive older and also culturally different, pre-Koniag, population. The skulls and bones of this hitherto unknown population showed a number of special features which deserve to be reported apart from the general study of the specimens.

The Pre-Koniags were an oblong-headed, moderate-sized people of much artistic ability, with some Eskimoid features, but related essentially to the oblong-headed American Indian. They were the first permanent inhabitants of the island, having settled there soon after the passing of glacial conditions, which, however, was fairly late—probably at about the beginning of the Christian era. They left deep, condensed deposits, in part already concreted, and larded with their own remains and those of animals. They apparently developed—or possibly brought in—cannibalism, and during the latter part of their period of occupancy, the evidence showed, did various curious things with their skeletal remains and especially with the skulls. It was very common to find a skeleton without the skull or with whole limbs missing, individual or even small groups of skulls apart, and spare bones disseminated throughout the accumulations. Some of the skulls and bones, moreover, showed conditions or artifacts which will be described in this paper.

DISEASE

If there be excluded one skeleton, in all probability from Russian times, that showed multiple and very marked tuberculous lesions, and cases of arthritis, a rare fracture, or a dental abscess, the numerous skulls and bones from Our Point, as well as those from the pre-White deposits elsewhere on Kodiak Island, are wholly free from disease. This is very remarkable, for the material is both extensive and exhaustive. There is no trace of any of the constitutional diseases or distrophies that leave their marks on the skeleton, and there are no tumors. Even fractures are much less common than with us. These findings apply to both the Pre-Koniag and the Koniag peoples.

The arthritic lesions in the elderly were common. They show the usual variety of alterations in the spine and the joints, but "mushroomhead" femora, relatively frequent in old Peru, do not occur.

The rarity of fractures, even in the ribs, points on one hand to the resistance of the bones, and on the other hand to rarity of such violence as would lead to fractures. There were, however, one or two skeletons in which several of the parts had been badly broken before death—possibly through encounters with bears.

As elsewhere in pre-White Alaska, there were no dental caries; but almost from the beginning of adult life there was progressive wear of the teeth, until eventually in instances the pulp cavity was exposed, infection followed, an apical abscess developed, and the tooth would be lost or rendered useless.

ANOMALIES

Cranial and skeletal anomalies, too, were rare in both the Pre-Koniags and the Koniags. As all through western Alaska, there was in both the Kodiak peoples occasional narrowing of the nasal bones at the root, and in rare instances a metopic suture or some form of an "Inca" bone. There are of course, as in all crania, numerous minor exceptional features, but they are of little importance.

DEFORMATION

A good many of the adult Koniag skulls, particularly males, show a slight asymmetry, probably caused by the subjects in infancy lying habitually on the back more to one side than to the other. Such asymmetries are common in brachycephalic crania everywhere and can hardly be called deformations. They may have had a slight effect on the cranial index in the males, but this could not be material. The Koniags had cradleboards, but used no bandaging of the heads of the infants.

The case was somewhat different among the Pre-Koniags. We do not know whether they had any form of a cradleboard; if they had, it would have been made of perishable material which would long since have disappeared. What is certain is that some deformation begins with this people. It was an occasional characteristic slight to moderate occipital compression that raised the parietal part of the vault, leaving the coronal region flat or even with a slight postcoronal depression. The deformation in only a very few cases was enough to necessitate the elimination of the specimen from the measuring; and fortunately such cases were so infrequent that they did not affect the high value of the collection.

ARTIFACTS

No artifacts were encountered on any of the Koniag skulls or bones, but some were present on those of the Pre-Koniags. They consisted in a few cases of drilled holes, in the skull, lower jaw, a scapula, or a pelvic bone, for the passing of a cord by which the bone or part was suspended; in one case of the insertion of artificial (ivory) eyes into the sockets of a skull; and in one or two cases of trephining. Brief descriptions of the individual cases, supplemented with photographs, follow.

DRILLED SKULLS AND BONES

Drilled skull.—U.S.N.M. No. 377738; from the intermediary pre-Koniag deposits, Our Point, Uyak Bay, Kodiak Island; a broken-out portion of an adult, probably male, skull that may have been trephined in the postcoronal region and was bored through at bregma. (Pl. 1, fig. 1, lower.)

This specimen, as far as the drilling at bregma is concerned, is an exact counterpart of some of those from Michigan reported in 1875-1877 by Gillman.[1] It shows at bregma a clean somewhat funnel-shaped perforation, 7 mm. in diameter dorsally and 4 mm. ventrally. A shelf deep inside the opening indicates that it was made first by a

[1] Gillman, H., Certain characteristics pertaining to ancient man in Michigan. Ann. Rep. Smithsonian Inst. 1875, pp. 234-245, 1876; La perforation crânienne du Michigan. Bull. Soc. Anthrop. Paris, vol. 11, pp. 435-436, 1876; Crânes perforés du Michigan, ibid., vol. 12, p. 82, 1877; Additional facts concerning artificial perforation of the cranium in ancient mounds in Michigan. Proc. Amer. Assoc. Adv. Sci., vol. 26, pp. 335-339, 1877. See also Fletcher, Robert, On prehistoric trephining and cranial amulets. Contr. North Amer. Ethnol., vol. 5, 1882; Cranial amulets and prehistoric trephining. Trans. Anthrop. Soc. Washington, vol. 1, pp. 47-51, 1882.

smaller and then by a larger drill; and 14 mm. posteriorly to it the bone had been cut across and its upper edge beveled, all the other edges being left raw and irregular. The whole piece may have been a crude disk, worn as a breastplate during some observances, or as an amulet on some occasions.

Plate 1, figure 1, shows the specimen, together with a previously unreported fragment from a mound in Michigan with three similar perforations.

A very good late report on artifacts of this nature was published in 1936 by Hinsdale and Greenman.[2] They refer to other post-mortem drilled or cut skulls, summarizing the subject thus (p. 12):

Crania with a single perforation at the vertex, drilled after death, have been found at four sites in southeastern Michigan and at three sites in western Ontario; crania with more than one perforation, or with an unknown number, have been found at one site in Michigan, at seven in Ontario, and at two in Ohio. Circular disks cut from human crania and perforated with two or more holes, are found in Ohio, Ontario, and New York.

In addition these authors report having found artificial perforations in the femora and tibiae of a skeleton. The case is unique and so curious that the details deserve to be quoted; they read (pp. 4-5):

There are also perforations in long bones from the Farmington site. Two femurs and two tibiae are perforated near the ends. Although dissociated from any other parts of a skeleton they apparently belonged to the same individual and were lying in normal articulation. A hole 5 mm. in diameter is in the distal end of the shaft of the left femur, anteroposterior. A hole in similar position on the anterior surface of the right femur was carried only to a depth of about 1 cm. The drill was started in the opposite surface of the femur to meet this hole but was only carried to a depth of about 1 mm. Another hole had been started in the anterior surface at the other end of this femur, at the distal end of the neck. It is 8 mm. deep. Both femurs have the heads cut so that each head is a disk about 23 mm. wide. At the other ends both condylar surfaces are missing, apparently they were severed (Pl. IV, Fig. 1).

The perforations in the two tibiae are at the proximal ends. Both articular surfaces have been cut off, and both anterior borders have been shaved down 1 to 2 cm. distal to the tuberosities. The distal ends have also been cut, but the greater part of each articular surface remains. There are two holes through the proximal end of each tibia, one anteroposterior and the other lateral, so that originally they may have intersected in the interior of the shafts, where cancellous tissue has not fallen away. The holes are from 6 to 7 mm. in diameter. The hole in the external surface of the left tibia could not have been more than 7 mm. deep.

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[2] Hinsdale, W. B., and Greenman, Emerson F., Perforated Indian crania in Michigan. Occas. Contr. Mus. Anthrop., Univ. Michigan, No. 5, pp. 1-15, 5 pl., 2 figs., 1936.

The perforations are pictured in plate IV of the above publication. They are small and served, it would seem to the present writer, for fastening together the respective femora and tibiae.

Drilled skull.—U.S.N.M. No. 374674; a normal Pre-Koniag middle-aged male; marks of knife across the forehead suggest that scalp had been removed artificially. (Pl. 1, fig. 2.)

The greater wing of the right sphenoid shows two smaller drill holes (4 mm. wide), that of the left sphenoid, one larger one (6 mm. wide), doubtless for thongs which attached the lower jaw to the skull, or by which the skull was suspended. The skull was one of several isolated crania laid down in such a way that they formed a right angle in the deposits. It is well preserved and has evidently been handled but little. There is no indication as to why it had received the special attention.

Drilled mandible.—U.S.N.M. No. 379244; from Our Point, Uyak Bay; the normal, well-preserved lower jaw of a Pre-Koniag boy of about 14. (Pl. 2, fig. 1.)

In each ascending portion below its middle is a drill hole 6 mm. wide; and a similar although incomplete perforation 5 mm. wide with concave base is seen anteriorly just below the root of the lateral right incisor.

Drilled scapula.—U.S.N.M. No. 379249; from Our Point, Uyak Bay; Pre-Koniag adult, sex uncertain; considerably damaged and acromion process evidently hacked off, but nothing pathological or unusual. (Pl. 2, fig. 2.)

A drill hole 5 mm. wide passes through the body of the spine about 3 cm. from its vertebral end; another similar but incomplete drill hole, with nicely concave base, is seen on the dorsal surface of the bone 3 cm. below the lower border of the glenoid cavity and 9 mm. from the axillary border of the bone.

Drilled sphenoid.—U.S.N.M. No. 379250; a portion of the great wing of a normal sphenoid, with a perforation 5 mm. wide near its pteric end; bone marked "black"[3] (Koniag), but may be displaced "red" (Pre-Koniag). (Pl. 3, fig. 1, right.)

The fragment, though found as such, was plainly broken off secondarily. It was the skull when whole that was drilled for suspension, as in No. 374674, and not the fragment.

[3] The term "black" was used throughout the excavations for the Koniag deposits, with "red" for the later and "blue" for the older pre-Koniag accumulations; and specimens from the different layers were marked accordingly.

Drilled pelvic bone of a child.—U.S.N.M. No. 379251; right ilium of a small child; bone is marked "black" (Koniag), but is probably a displaced "red" (Pre-Koniag). (Pl. 3, fig. 1, left.)

Near the anterosuperior spine is a perforation 6 mm. wide made from the back forward and very similar to those on the other drilled ilia. There may possibly have been another hole farther on, but the middle portion of the upper part of the ilium has been broken off. The bone is strong and rather flat but shows nothing pathological.

Drilled pelvic bone.—U.S.N.M. No. 379248; from Our Point, Uyak Bay; normal right Pre-Koniag pelvic bone. (Pl. 3, fig. 2, right.)

The ilium near its upper border shows two drilled holes, each 5 mm. in diameter. The bone is that of a young adult, rather small but not weak, sex uncertain. It shows no injury and no marked handling. Posteriorly, a short distance below the anterior perforation is seen the beginning of another, consisting of a sharp rim with a smooth, large dotlike hollow in the middle.

Drilled pelvic bone.—U.S.N.M. No. 377701; from Our Point, Uyak Bay; right pelvic bone of a Pre-Koniag adult male. (Pl. 3, fig. 2, left.)

The ilium shows four borings, three of 8 mm. diameter and one of 6 mm., made without much care from the back forward. Their location and disposal are shown in plate 3, figure 2, left. They were doubtless made for a vertical suspension of the bone, or possibly even of the pelvis as a whole; but the bone was found alone. The pubic part of the specimen had been broken off, but that might have been incidental. The bone itself is normal and indicates a small presenile male individual.

TREPANATION

In the course of the excavations at Our Point, Uyak Bay, Kodiak Island, the "red" or later pre-Koniag deposits yielded a human skull that shows a form of trepanation.

Such operations have not as yet been recorded from anywhere else in Alaska, but there is an example of the practice in the United States National Museum collections from Kagamil Island, and another from Prince William Sound. Several cases also have been found among remains of related type in the oldest deposits at the mouth of the Fraser River[4] and in those of the nearby Boundary Bay. Gill-

[4] Smith, Harlan I. (quoting Hrdlička), Trephined aboriginal skulls from British Columbia and Washington. Amer. Journ. Phys. Anthrop., vol. 7, pp. 447-452. 1924. One or two additional specimens recovered since the publication.

man[5] mentions in addition a skull reported to him from Santa Barbara, Calif., which showed an artificial perforation in the vault that may possibly have been made in life. Several cases of skull trephining are on record or await publication from different parts of the United States and northern as well as southern Mexico (Zapotec tombs, Caso; unpublished), besides the many from Peru and Bolivia.[6]

The description of the Kodiak specimen follows:

Trephined skull.—U.S.N.M. No. 379252; from later pre-Koniag deposits, Our Point, Uyak Bay; skull of an elderly woman, damaged before coming into deposits, breaks in basal parts, lower face missing, otherwise normal. (Pl. 4, fig. 1.)

Along the middle of the upper third of the frontal and adjoining portion of the parietals is a smooth elliptical depression 6 cm. long, at maximum 2.1 cm. wide, and up to 4 mm. deep, the result of an ancient operation—incomplete trepanation. The hollow in all probability was made by scraping, long before the death of the woman. There is no indication as to why it was made, and there was a perfect healing.

Trephined skull.—Reported with the preceding may be the case of skull U.S.N.M. No. 262170, from Knights Island, Prince William Sound; gift of Dr. F. M. Boyle. (Pl. 4, fig. 2.)

The skull is that of a young adult female, probably not very ancient. It shows some disturbance of development—the occiput is bulging and somewhat asymmetrical, with a rather marked supralambdoid "set-back" of the parietals; the left parietal shows over the eminence a fairly large, old, well-healed lesion, which, however, did not affect the inner wall and so may not have been the cause of the operation; yet the thickening of the external plate about the lesion is somewhat pronounced especially anteriorly, where it extends nearly to the rear margin of the lower perforation. Aside from these features the specimen is normal.

The postcoronal upper two-thirds of the left parietal of this skull shows two good-sized openings; one of these is surely due to an

[5] Gillman, H., Certain characteristics pertaining to ancient man in Michigan. Ann. Rep. Smithsonian Inst. 1875, p. 242, 1876.

[6] See Lumholtz, Carl, and Hrdlička, Aleš, Trephining in Mexico. Amer. Anthrop., vol. 10, No. 12, pp. 389-396, 1897; Cosgrove, C. B., A note on a trephined Indian skull from Georgia. Amer. Journ. Phys. Anthrop., vol. 13, No. 2, pp. 353-357, 1929; Shapiro, H. L., Primitive surgery: First evidence of trephining in the Southwest. Nat. Hist., vol. 27, No. 3, pp. 266-269, 1927; Hrdlička, A., Trepanation among prehistoric people, especially in America. Ciba Symposia, vol. 1, No. 6, bibliography, 1939.

operation, and the other probably is. The upper hole is circular, 2 cm. in maximum diameter, 1 cm. in the rear of bregma and involving a portion of the sagittal suture. The edges of the opening are fairly sharp, its external border is beveled, the internal border but little affected. The opening bears all the marks of an old, well-healed trepanation. The bone behind it externally is somewhat thickened but otherwise looks normal.

The lower lesion is not easy to describe. From above downward it consists of a nearly circular portion, 7 mm. in greatest width, and apparently cut out in that form. Below this the outer wall of the skull has been scraped and in it there has been made an oblong, somewhat obliquely quadrilateral opening 22 mm. long by 13 mm. wide. This now has thin and very sharp borders, communicates with the small circular aperture above, and reaches antero-inferiorly, by what looks like a broad crack, a small focus of perforative osteitis. The inner table about this whole second opening is somewhat uneven, but there is no breaking down of the bone, and the whole wound, less the small osteitic lesion, has long since been well healed.

The face and base of the skull are normal.

Trephined skull.—Still another specimen that may well be reported here is U.S.N.M. No. 243974, a normal skull of a Pre-Aleut elderly female from Nazan Bay, Atka Island; collected in the early seventies by William H. Dall. (Pl. 5, fig. 1.)

In the anterior third of the right parietal, 3.5 cm. from the coronal and 1.7 cm. from the sagittal suture, there is an oval opening 12 mm. long by 7 mm. wide, with beveled edge all around and some brown discoloration outside of this. The inner surface of the skull about the opening is entirely normal. The bone about the opening shows healing, but little if any restitution.

It seems impossible to diagnose the lesion as anything else but a trepanation, during life, by cutting. But there is no indication as to why the operation may have been performed; the vault of the skull is wholly normal and shows only one possible injury—a moderate-sized, irregular-edged opening in the unusually thin right postero-inferior portion of the frontal, 3 mm. above the sphenofrontal suture, which appears to be accidental—its edges are rough, there is no beveling, and no trace of cutting (Pl. 5, fig. 2). There are many post-mortem defects in the orbits, the maxillae, and neighboring parts, none of which, however, can have any connection with the trepanation.

Peculiar lesions in skull bones of an infant.—U.S.N.M. No. 372883; from Our Point, Uyak Bay; two portions of the skull of a Pre-Koniag infant. (Pl. 6.)

Present, a large portion of the right and a piece of the left parietal. Each shows curious lesions that, especially on the left fragment, appear to have been artificially produced, although they may possibly have been due to some natural cause.

The right bone shows a streaked outer surface, due to corrosion by roots. In its lower third is a large, nearly circular lesion that looks as though a disk of the bone had been cut out. The edges of the opening are sharp, and its inner border is naturally beveled.

The part of the left bone presents two lesions, one nearly circular, the other nearly right-angular, with the angle itself rounded. The bone is thin, apparently normal, and without any traces of disease or inflammation. The openings look exactly as though someone had cut out two pieces of the bone, but the edges of the openings are almost knife-sharp, and ventrally there is a distinct beveling about each of the defects.

The specimens are the only ones of that nature found in the Far North. They cannot, it would seem, well be trepanations, but what else they could be seems impossible to decide. They might possibly be defects caused by absorption from within, but it is hard to conceive what could cause such odd absorptions.

BREAKING OUT, CUTTING

A broken-out portion of face.—U.S.N.M. No. 379245; from Our Point, Uyak Bay; a normal specimen, Pre-Koniag, strong adolescent male. (Pl. 7.)

The joint maxillary portion of the face has intentionally been broken out at the level of the maxillozygomatic sutures, and the nasal septum, the turbinated bones, and the nasal wall of each antrum were removed; but the good denture, not fully complete, and the whole front of the piece, as well as the palate, were fully preserved. It is difficult to understand the motives behind the making of this piece, or for what purpose it could have served; but it is surely not accidental.

Trepanation on the humerus.—U.S.N.M. No. 332608(6); from Point Hope (old burials), Alaska; normally developed medium-strong right male humerus, 32.3 cm. long; the lower end shows marked arthritic changes, with upper end unaffected. (Pl. 8, fig. 1.)

Eight cm. from the upper end of the bone, externally, at the upper limit of the deltoid ridge, there is a clean-cut somewhat lozenge-shaped opening, 12 mm. long by 8 mm. wide. The operation was done in life, was uneventful, and was followed by perfect healing of the edges. There is not the slightest fracture nor any sign of inflammation about the locality; yet the shape, size, and perfect edges of the opening can leave no doubt as to its representing a planned and successful operation.

This is the only known example of a trepanation of a long bone from the Far North, or from anywhere else in the Americas.

Cutting away of the head of a femur.—U.S.N.M. No. 372822; from Our Point, Uyak Bay; normal right moderate-sized femur from a Pre-Koniag pre-middle-aged female. (Pl. 8, fig. 2.)

The head of the bone has been cleanly cut away post mortem with a sharp stone knife. The cut is so neat that it must have been made while the bone was still fresh. This is the only specimen of this nature found in the Kodiak excavations, or so far in Alaska, and there is nothing to indicate the object of the cutting. The same deposits, however, yielded several cups each made out of the head of the humerus of a bear, and just as the people made "baby" stone lamps, they may also have made a "baby" bone cup. It may, of course, have been used as a handle to some tool, or for still another purpose.

SKULL WITH IVORY EYES

One of the first outstanding specimens recovered from the deposits at Our Point, Uyak Bay, was the skull, less lower jaw, of a middle-aged Pre-Koniag. The orbits of this skull had originally been filled with some organic mass, possibly gum, which eventually left but a dark, loose residue; and in this mass in each orbit was fixed an ivory eye, with pupil of a black stone. (Pl. 11, fig. 1.)

The specimen was found in the very first week of the work on Kodiak. It lay with its face down in what were designated the "red" or later pre-Koniag layers. It was alone, without the lower jaw or any other part of the skeleton. Without anticipating anything unusual I carefully took it out, saw the orbits filled with what looked like nearly black "dirt" and began to shake this out, when there dropped into my hand an ivory eye; and at the same time Dr. Rich, who was looking on, called my attention to something white that dropped out of the other orbit to the ground, and which proved to be the mate of the first eye.

Plate 11, figure 1, shows the two eyes in their natural size. Nothing of such nature has ever come out of the deposits before or since, and nothing similar has ever been known from any part of Alaska before; recently (1940), however, some related finds of this nature were made by Rainey in an interesting new site at Point Hope.[7]

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[7] Rainey, Froelich, A new form of culture on the Arctic coast. Proc. Nat. Acad. Sci., vol. 27, No. 3, pp. 141-144, 1941.

The Uyak skull was a normal specimen. It had evidently been handled, so that some of the teeth were lost. It may have been the head of some outstanding hunter or chief or a distinguished enemy; in the first case it would have been a memorial, in the latter a prized trophy.

SKULL CUPS, BOWLS, AND DIPPERS

The Pre-Koniags of Uyak Bay, Kodiak Island, used a part of the human skull occasionally as a cup, bowl, or dipper. They broke out a suitable piece and trimmed it more or less to suit their purposes.

All these specimens came from the "red" or later pre-Koniag layers of the deposits. At this period the people were certainly not shy of human bones; they practiced cannibalism and must have done all sorts of things with skulls and bones as shown by the skeletal remains in the deposits.

Skull bowls were used, it is known, in Tibet, and may have had a wider distribution in eastern Asia. The practice, in fact, was once widely distributed over the world, even among peoples of the white race, and was very ancient, dating back to at least the Upper Paleolithic (Magdalenian, Solutrean).[8]

In America, in the words of Friederici,[9]

> the skull cup may be followed over the whole continent. It is found in the region of the great Canadian lakes, in Massachusetts and probably in Carolina, in Sinaloa and Michoacan, in Darien and in the Antilles. In South America it is met with in Venezuela, in the realm of the Incas, among the Maynas, Mochos and in the Amazon region. Among the Chaco tribes it was especially reported in the Abipones, Tobas, and Macobies, while the Matacos drank from cups made of the scalps. Especially good information in this respect exists about the Araucano, among whom the cups from the skulls of the Governors Valdivia and Loyala were their most prized trophies.[10]

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[8] See Breuil, H., and Obermaier, H., Cranes paléolithiques façonnés en coupes. L'Anthrop., vol. 20, pp. 523-530, 1909. See also Kuhn, A., Namen von Gefässen, Namentlich von Kochgefässen. Zeitschr. Ethnol., vol. 9, p. 489, 1877.

[9] Friederici, G., Skalpieren und ähnliche Kriegsgebräuche in Amerika. Inaug. Diss., p. 96, Braunschweig, 1906.

[10] Idem, bibliography. There is here, regrettably, some confusion between cups made of human skulls and cups or vessels of clay in the form of skulls. Thus Chase, Henry E., Notes on the Wampanoag Indians, Ann. Rep. Smithsonian Inst. 1883, p. 904, says the Wampanoags "have large drinking-cups made like skulls"; and Holmes, William H., Ancient pottery of the Mississippi Valley, 4th Ann. Rep. Bur. Ethnol., p. 407, referring to the prehistoric industry of Arkansas, speaks of "vessels imitating the human head."

In South America, particularly in Brazil and Chile, cups or bowls made of human skulls were reported, according to Vignati,[11] from the Guaycurie, Abipon, Chiriguano, Toba, and Araucano-Mapuche Indians. The making and the use of such cups was generally associated with war; the skulls used were those of trophy heads, and the drinking from such cups was more or less of a ceremonial nature.

The incidence of cups or bowls made from human skulls in North America is as yet not sufficiently clear. Specimens of this nature could readily be passed over by the finder, or be mentioned where the physical anthropologist would not be likely to see it. An example is the brief report by E. R. Quick on "A Prehistoric Cup Made from a Human Cranium," from Cedar Grove, Ind., published in the January 1881 number of the Journal of the Cincinnati Society of Natural History. The "cup or bowl was made of a child's skull," and accompanied an old man's skeleton. In this case,

> the base of the skull has been roughly cut away and scraped smooth, leaving an irregular margin or rim to the vessel. Both the inner and outer surface has been scraped with some rough-edged tool, leaving numerous scratches. Two holes were drilled through the side, near the upper part of the cup, for the purpose of mending a crack by tying the fractured parts together.

References to similar practices may doubtless be found in the vast ethnographic and archeological literature on the North American aborigines. Dr. J. R. Swanton, of the Bureau of American Ethnology, has given me the following information:

> In my own notes I find but one reference and that merely states that as a war trophy besides the scalp they sometimes took the upper part of the skull. This is in Lawson's History of Carolina, Raleigh edition, page 321. It does not state that the part so taken was used definitely as a cup. And, in Pierre Margry's great work, "Découvertes et éstablissements des Français dans l'ouest et dans le sud de l'Amérique septentrionale," volume 5, page 96, some of the northern Indians threaten to drink out of the skulls of their captives.

The specimens in the United States National Museum are as follows:

Skull bowl.—U.S.N.M. No. 379243; from Our Point, Uyak Bay; the rear half of a normal skull of a "blue" (deep) Pre-Koniag adult female, shaped artificially though crudely into what evidently served as a cup or a bowl. (Pl. 9, lower.)

The specimen now has a hole near the center caused possibly by one of my boys' picks, though it may have been made by the people

[11] Vignati, M. A., Los cráneos trofeo. Arch. Mus. Etnográfico, No. 1, pp. 93, 118-120, 153, 1930.

"killing" the cup after the decease of the owner, as they habitually did with the stone lamps and other articles. The blow was delivered from the outside, causing about the wound characteristic peelings of the inner table.

Skull bowl.—U.S.N.M. No. 377738; from Our Point, Uyak Bay; skull of a Pre-Koniag female. (Pl. 10, lower.)

The rear third of the parietals and the occipital squama were cut off and rounded to a moderate-sized bowl 10 cm. wide by 12 cm. long. The ventral ridges of the occipital were leveled to make the interior of the bowl somewhat more even and, incidentally, to give a better thumb-spot for handling the vessel. It would have been very useful to drink from, or to contain more or less liquid food.

Skull dipper.—U.S.N.M. No. 379247; from Our Point, Uyak Bay; occipital bone of a Pre-Koniag, probably an old male. (Pl. 9, upper.)

The borders of the bone were trimmed all around, and the right lower end was left protruding somewhat to form a convenient handle. The specimen could have been used as a shallow cup from which to drink water or as a ladle for dipping out more or less liquid food. It shows no special marks, but considerable handling.

Skull dipper.—U.S.N.M. No. 379246; from Our Point, Uyak Bay; left parietal of a Pre-Koniag adult. (Pl. 10, upper.)

The specimen had been trimmed all around to form a dipper, the lower left corner being left somewhat protruding for a handle. There is nothing extraordinary about the bone itself, and it bears no marks; but it had been broken ("killed" ?) and some pieces were lost before it came into the deposits.

Skull dipper from Aleutian Islands.—U.S.N.M. No. 379253; rear portion of the skull of a sub-middle-aged male, probably Pre-Aleut, from one of the mummy caves on Kagamil Island, cut into the form of a large dipper or a bowl. (Pl. 11, fig. 2.)

The piece consists of the occipital, a small part of the right and large part of the left parietal, and the left temporal, with a portion of the base which served for a handle. The parietals and temporal were cleanly cut by a very sharp knife. The whole formed a spacious bowl, and the cut edges are worn, showing considerable use. The dish had evidently been used only for liquids, for its surfaces show no abrasion. The rostrum of the stella turcica had been removed, probably to facilitate holding, and a part of the squama of the cut left temporal has been broken off, either during or after the deposition of the specimen in the cave.

SUMMARY AND CONCLUSIONS

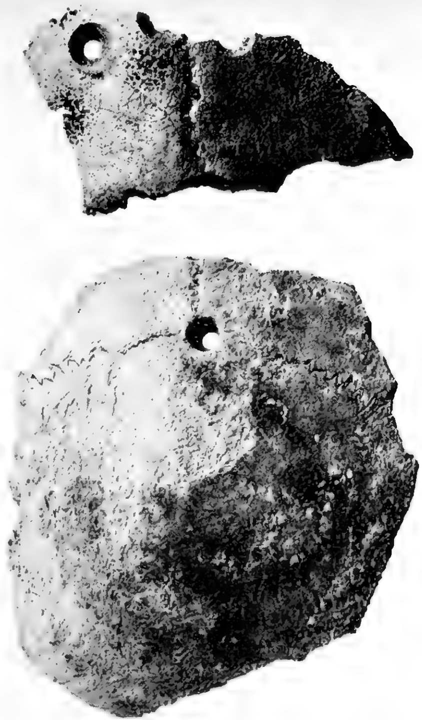
This paper calls attention to the limited pathology and grosser anomalies, as well as the various artifacts, shown by the skeletal remains of the pre-Russian and particularly the Pre-Koniag people of Kodiak Island, and reports a few related specimens from southwest Alaska.

The Kodiak remains show absence of all constitutional diseases that leave their marks on the skeleton, with the exception of senile arthritis.

The artifacts, limited largely to the later period of the Pre-Koniag people, include some slight grades of head deformation; drilling of skulls or bones for suspension as charms or trophies; trepanation; the cutting of bones or breaking out of parts for some utilitarian or other purpose; and the making of cups or bowls from human skulls.

An apparently significant fact is that most if not all the drilled bones are male, and the three trephined crania all female.

There are here presented thus, from the Far Northwest, a whole series of observances with the human skull and bones previously unknown from that area. As excavations in those regions proceed, this field will doubtless be further enriched. It shows the existence among the peoples of pre-White western Alaska of considerable ceremonialism which, together with mummification, sacrifice of slaves, and other practices, establishes on the one hand further cultural links with the rest of the American continent, and on the other hand suggests strongly an ancient pre-American origin of all these usages. It increases greatly the need of the extension of explorations beyond the Bering Strait and Sea into the vast and archeologically still largely unknown territories of eastern Siberia.

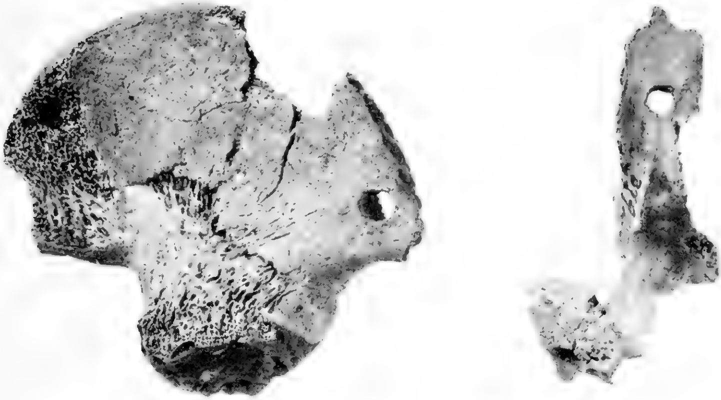


1. Upper, fragment of an Indian skull from Michigan, showing drillings in the top of the skull. U.S.N.M. No. 147272. Lower, a portion of a Pre-Koniag skull from Our Point, Uyak Bay, Kodiak Island, showing a drilled hole at bregma. U.S.N.M. No. 377738.

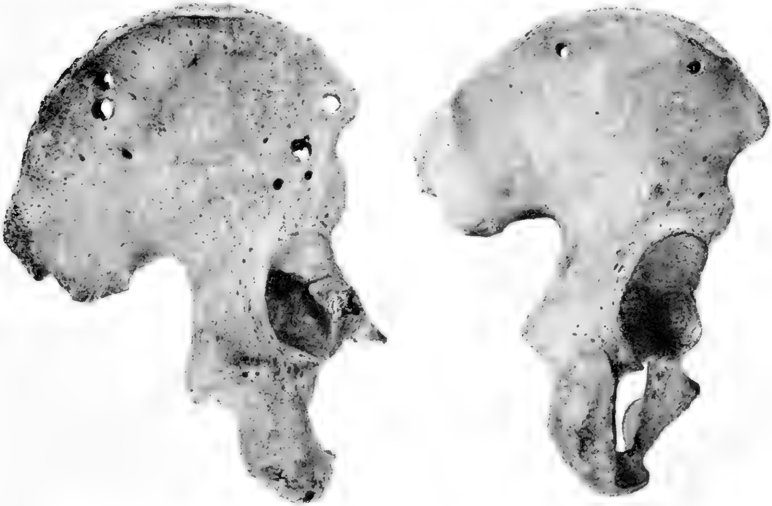
2. A Pre-Koniag male skull from Our Point, Uyak Bay, Kodiak Island, with two drilled holes in the right temple region and one in the left (not shown), for suspension. U.S.N.M. No. 374674.

1. Lower jaw of a Pre-Koniag boy of about 14, from Our Point, Uyak Bay, Kodiak Island, drilled for suspension through each ascending portion above the angle, and also incompletely below right lateral incisor. U.S.N.M. No. 379244.

2. Pre-Koniag right scapula, from Our Point, Uyak Bay, Kodiak Island, showing one complete and one incomplete drill hole, for suspension. U.S.N.M. No. 379249.

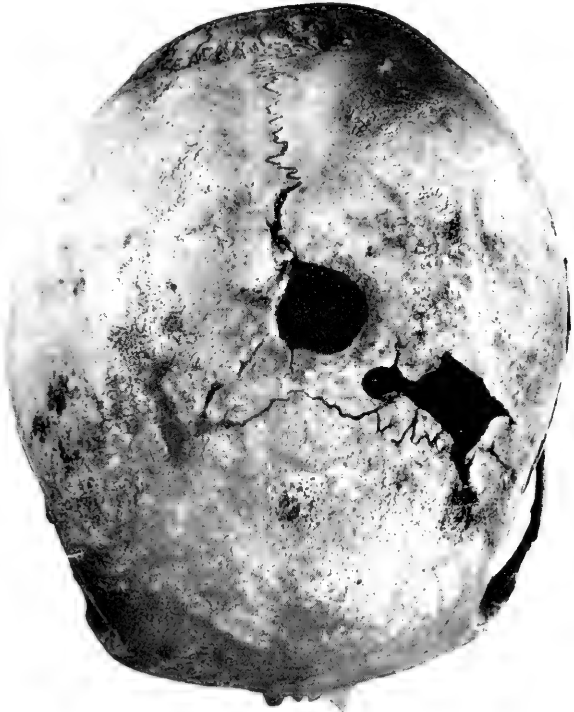


1. Pre-Koniag specimens from Our Point, Uyak Bay, Kodiak Island. Left, child's pelvic bone, drilled for suspension. U.S.N.M. No. 379251. Right, a portion of a sphenoid of an adult skull, drilled for suspension. U.S.N.M. No. 379250.



2. Pre-Koniag pelvic bones from two separate subjects, drilled for suspension; from Our Point, Uyak Bay, Kodiak Island. Left, U.S.N.M. No. 377701; right, U.S.N.M. No. 379248.

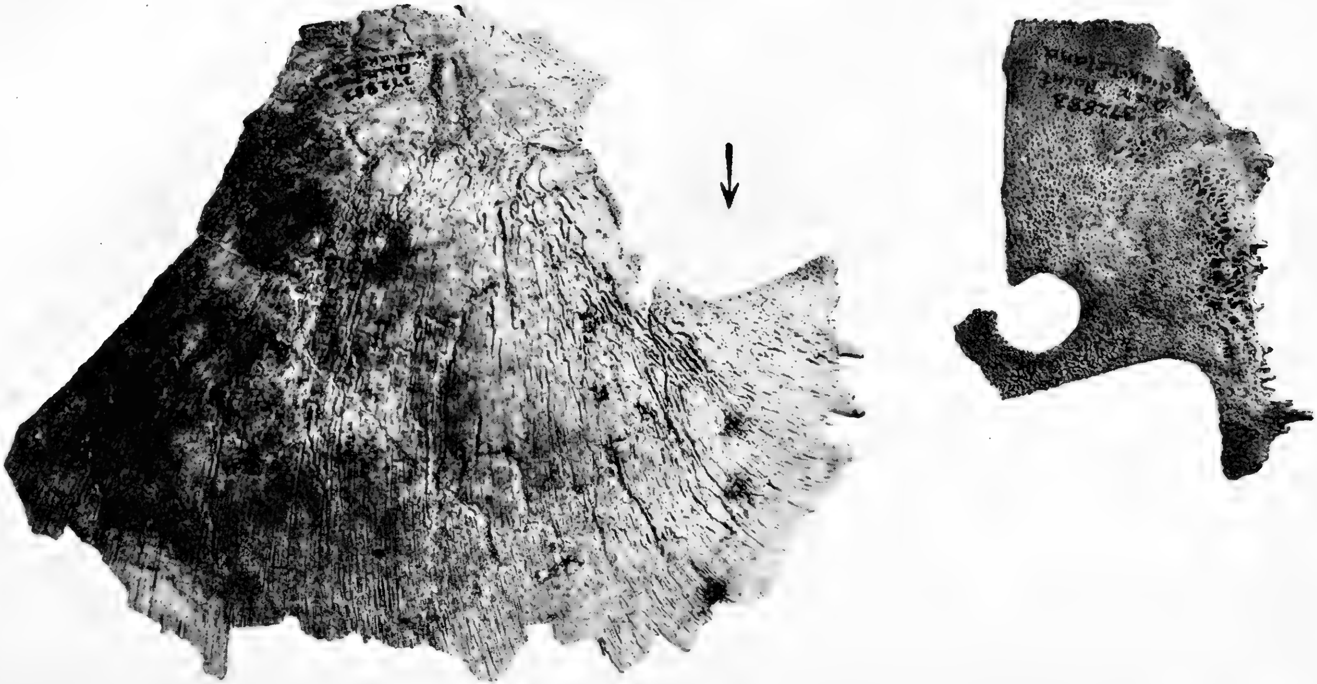
1. Skull of an elderly Pre-Koniag woman, showing incomplete trepanation; from Our Point, Uyak Bay, Kodiak Island. U.S.N.M. No. 370252.



2. Female skull from Knights Island, Prince William Sound, showing trephining. U.S.N.M. No. 262170.

1. Skull of an elderly pre-Aleut woman, from Atka Island, Aleutian Chain, showing trepanation. U.S.N.M. No. 243974.

2. Enlarged view of trepanation illustrated in figure 1, showing beveling of the border. The discoloration about the opening may possibly be due to some inorganic material applied originally to the wound.



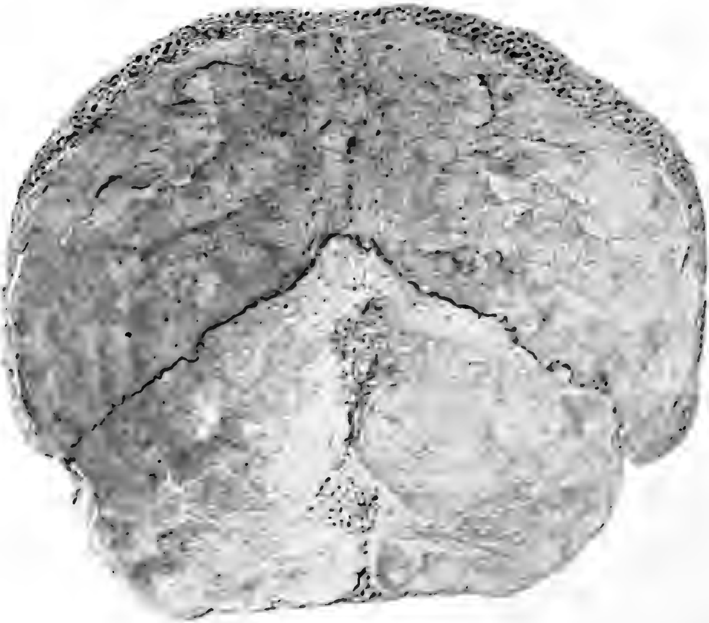
Parts of a Pre-Koniag infant skull, from Our Point, Uyak Bay, Kodiak Island, showing lesions resembling trephinings.
U.S.N.M. No. 372883.

Front and rear view of a purposely broken out Pre-Koniag maxilla, from Our Point, Uyak Bay, Kodiak Island. U.S.N.M. No. 379245.

1. Right male humerus, from Point Hope, Alaska, showing trepanation. U.S.N.M. No. 332608 (6).

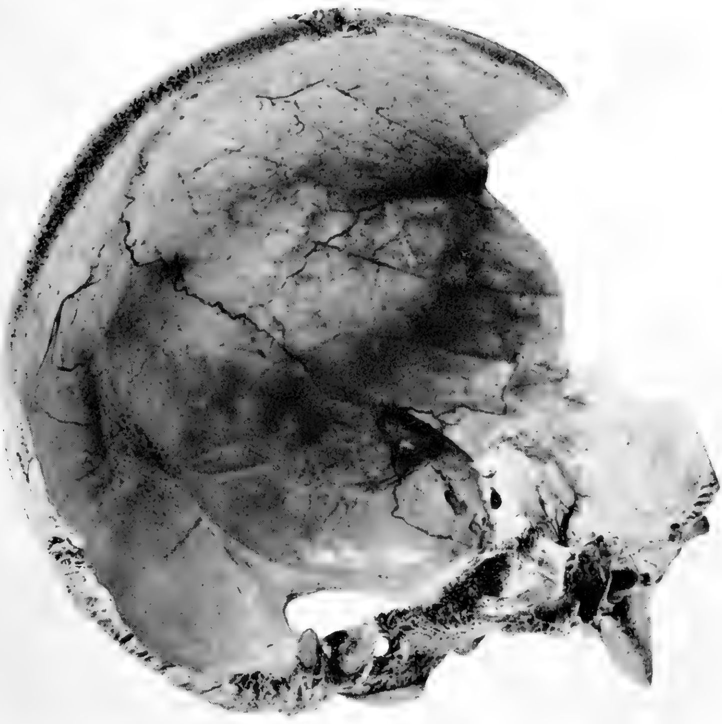
2. A Pre-Koniag female femur, from Our Point, Uyak Bay, Kodiak Island, the head of which has been neatly cut off. U.S.N.M. No. 372822.

Pre-Koniag dipper and bowl made from human skulls; from Our Point, Uyak Bay, Kodiak Island. Upper, U.S.N.M. No. 379247; lower, U.S.N.M. No. 379243.



Pre-Koniag dipper and bowl made from human skulls; from Our Point, Uyak Bay, Kodiak Island. Upper, U.S.N.M. No. 379246; lower, U.S.N.M. No. 377738.

1. Ivory eyes, from a Pre-Koniag male skull, Our Point, Uyak Bay, Kodiak Island. Natural size.



2. A dipper made from a human skull, from Kagamil Island, Aleutian Chain. U.S.N.M. No. 379253.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 101, NUMBER 5

Roebling Fund

ON SOLAR-CONSTANT AND ATMOSPHERIC TEMPERATURE CHANGES

BY
HENRYK ARCTOWSKI

(Publication 3641)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
NOVEMBER 7, 1941

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PREFACE

In recent time, correspondence reaching me from various sources convinces me that the view is growing among experts that the variation of solar radiation is a weather element of first-rate importance. This would not have occurred had it not been for the generous, enthusiastic, and discriminating support afforded by Mr. John A. Roebling to the Smithsonian solar investigations throughout the past 20 years.

When the lamentable war in Europe stranded Dr. Arctowski in this country, it seemed to me that it would be very helpful if an unbiased research meteorologist of Dr. Arctowski's long experience and standing would make a study of the supposed solar variation with reference to world weather conditions. I proposed this project to Mr. Roebling. He enthusiastically embraced it, and generously provided means for the investigation. The present paper represents the first fruits of this work, and it is published under a grant from Mr. Roebling.

Dr. Arctowski has confessed to me that he undertook the assignment unbelieving in Smithsonian claims regarding the importance of solar variability. He said that he had intended to work faithfully on the problem for 2 or 3 months, and then, finding nothing, to tear up his papers and resign, as he could not accept compensation under false premises. But to his surprise he became fully convinced within a few weeks that solar variation is a main cause of weather changes.

But obvious as he finds the influence of solar variability in weather to be, the complexity of its effects is baffling. He regards his present paper, which is the fruit of 2 years of the most devoted and unremitting work, as my colleagues of the Institution will testify, to be merely a preliminary survey of some of the factors which must be considered.

Dr. Arctowski asked me to read his paper critically in manuscript. I approached the matter, not as a qualified meteorologist, but as one experienced in the measurement of solar radiation. It appeared to me that my comments from this viewpoint might add to the interest of readers of Dr. Arctowski's paper; hence this introduction.

I think no one who has not struggled for many years, as my colleagues and I have done, with the actual field work and computations in solar-constant measurements can have a vivid appreciation either of the strength or of the weakness of our results.

The ocean of atmosphere, even above our best desert mountain stations, is constantly changing its transparency. We have not the advantage of variable-star observers, who can compare their chosen star object with dozens of other stars nearby, the rays of all of which experience nearly identical percentage losses within our atmosphere. The observer of solar variability can have no comparison stars. He must compare absolute measurements of today with those of tomorrow and succeeding days, and evaluate the sun's small percentage variation by differences of total radiation. This makes it well-nigh impossible to obtain the necessary degree of accuracy to disclose the solar variation.

The reader will find that almost none of the cases of solar variation which Dr. Arctowski quotes in his paper, and which he correlates with atmospheric and weather changes, reach the magnitude of one-half of 1 percent. To my colleagues and myself, who know so well the multitudinous sources of error in solar-constant determinations, it seems only by chance that any single isolated instance of solar variation of such small magnitude as one-half of 1 percent should deserve individual consideration. It is true, however, that Dr. Arctowski fortifies his data by using only cases where there is a regular approach and recession accompanying lows and highs of the solar constant. Yet in my own studies of correlation between solar variation and weather records, I have almost always thought it necessary to use mean values of many cases of solar variation in order to reduce accidental errors.

But Dr. Arctowski, as a meteorologist rather than a solar-constant observer, is more impressed by the changeability of a multiplicity of terrestrial circumstances than by the fallibility of individual determinations of solar-constant fluctuations. Hence he feels the necessity of dealing with individual cases, having no confidence that they are sufficiently comparable among themselves to give sound mean values. I greatly regret that Dr. Arctowski had only preliminary solar-constant results to work with in this paper. In further studies he can use our best mean values. And soon there will be available to him results from a new method which I mention in the next paragraph.

What is needed, and I fear can never be supplied unless war conditions cease, and unless far greater financial support becomes available, is a continuous daily record of the solar variation over many years, with the individual mean daily solar-constant values probably accurate to one-fifth of 1 percent. It is true that in July 1941 we introduced a new method of noting solar variation, in which the measures are restricted to the blue-violet spectral region where percentage changes are larger and where several sources of error are eliminated. Our three desert mountain stations are now all carrying on these new observations in addition to the older method of solar-constant measurement. It is hoped that this new method will give greater certainty in observing solar-constant variation. But the requisite certainty and accuracy probably can come only by occupying as many as 10 of the most favorable desert mountain sites to be found in the whole world. War conditions render this impossible for the present.

Dr. Arctowski covers so wide a field in his paper that the reader may appreciate a few words of guidance, lest he become confused among a multitude of considerations and lose the thread which connects all of them to the fundamental thesis, the influence of solar variation on the weather.

In sections 1 and 2, by using mean results of many observed solar-constant changes, including both maxima and minima, Dr. Arctowski sets before us the average duration and amplitude of solar changes, and shows conclusively the correlation of solar-constant variation with visual solar changes, and with terrestrial weather. Thus the main thesis is first of all established. But even while employing correlations of means of many occurrences to demonstrate the reality of the phenomenon of solar variation and its importance, he lays almost equal stress on the dissimilarity of individual solar outbreaks, and on the differences in terrestrial responses to them.

The bulk of the paper which follows is an attempt to set forth the many terrestrial considerations to be employed in trying to localize the primary effects of solar changes in different strata of the atmosphere, in different regions of the earth, and at all seasons of the year. For one would desire to be able to say definitely: When an increase or a decrease of solar radiation occurs it will produce such and such terrestrial effects.

In section 3 are considered the waves in atmospheric pressure whereby centers of action are displaced, and regularity in solar-variation effects is rendered impossible. This leads in section 4 to a consideration of areas of positive and negative pressure changes throughout the whole world. The anomalous results of such considerations lead Dr. Arctowski in section 5 to widen his investigation to include the upper air. For here, direct hits would more probably result from solar changes. There were available at the United States Weather Bureau results of daily night radio meteorograph soundings since July 1939, for numerous American stations. These were made available to Dr. Arctowski, and he has done a vast amount of original work in computing and plotting these observations, for the purpose of comparing temperatures and pressures of large areas of atmosphere at different levels. Samples of his results are extensively given by tables and charts included in this paper, which should make it a valuable source of material for other researches. Section 5 includes direct comparisons of certain individual solar-constant changes with upper-air data. The results show that no single stratum of the upper air can be regarded as the exclusive home of solar-variation hits.

In view of the paucity of cases where direct individual comparisons of day-to-day solar changes with upper air data are at present available, Dr. Arctowski moves in subsequent sections 6, 7, 8, 9, 10, and 11 to consider seasonal changes of upper-air data in many regions, thus substituting as an inciting cause of meteorological changes the well-known regular fluctuations in the yearly insulation for the variable changes found in the solar constant.

He then draws attention in section 12 to the eventual necessity of taking a day-to-day world-wide outlook both of surface and upper-air conditions under the reaction of solar changes. He reverts in sections 13, 14, and 15 to a search over wide areas for regions of direct hits in cases of individual solar-constant variations. This includes an extensive table of atmospheric altitudes at the prevailing temperature $-50°$ C., at 25 American stations, for the last half of October 1939. Section 16 is devoted to a comparative discussion of the behavior of meteorological elements at different atmospheric levels, and the flow of waves among them.

Finally follows the author's summary and conclusion. One sees that while sure of the importance of the meteorological effects of solar variation, Dr. Arctowski is appalled by the complexity of the scientific problems it entails. At the very end he almost plaintively calls for improved and continuous data on solar variation, so that he ends where this introduction begins. I wish I might see my way to assure him that such data could soon be possible of attainment.

C. G. Abbot,
Secretary, Smithsonian Institution.

Roebling Fund

ON SOLAR-CONSTANT AND ATMOSPHERIC TEMPERATURE CHANGES

By HENRYK ARCTOWSKI

Admitting that the intensity of solar radiation outside the terrestrial atmosphere may change from day to day, the problem has been to find out how our atmosphere reacts to such impulses of excess or deficiency of radiant energy. If the direct effect is felt in the stratosphere, we should be able to show how these impulses are transmitted into the troposphere and to the earth's surface. We should also know why in some cases the reaction is felt directly and without retardation at the bottom of our atmosphere and why the direct effect is geographically localized, in the stratosphere as well as at the earth's surface.

A study of the American meteorological radio-sounding data for days of Smithsonian solar-constant maxima and minima has given results opening a wide field of research work that must be undertaken in order to be able to give a really satisfactory answer to the foregoing questions—questions concerning the ultimate cause of weather changes.[1]

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[1] C. G. Abbot published his first paper on the variability of the solar constant in 1903 (Smithsonian Misc. Coll., vol. 45, p. 74, July-Sept.); in 1904, making use of monthly temperature means of 89 stations, S. P. Langley published a paper "On a possible variation of the solar radiation and its probable effect on terrestrial temperatures" (Astrophys. Journ., vol. 19, p. 305). The first extensive comparison of solar-constant data with monthly temperature means was made by C. G. Abbot and F. E. Fowle and published in 1908, in vol. 2 of the Annals of the Astrophysical Observatory of the Smithsonian Institution.

From the preface of that volume is taken the following statement: "Mr. Langley expressed the hope that careful study of the radiation of the sun might eventually lead to the discovery of means of forecasting climatic conditions for some time in advance. It is believed that the present volume will aid materially to show how far that hope may be justified, for it contains careful and comparable measurements of the solar radiation, extending over several years. These indicate that the sun's radiation alters in its intensity from time to time, and that these alterations are sufficient to affect the temperature of the earth very appreciably."

SMITHSONIAN MISCELLANEOUS COLLECTIONS, VOL. 101, NO. 5.

1. THE SOLAR PROBLEM

For the years 1926 to 1930, 72 days of selected maxima and 82 days of minima of solar values were chosen,[2] and the means for the 5 preceding and 5 following days gave the figures below (calories):

	−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5
Max.	37	35	36	37	41	1.944	41	38	34	36	36
Min.	39	40	41	38	35	1.931	34	38	40	40	38

The mean duration of the variation is 6½ or 7 days. The Greenwich data of the extent of faculae[3] for the same dates as those above show variations of the same duration but with a belated minimum and maximum of 1 or 2 days.[4]

Comparisons of the diagrams of all the data[5] show that in most cases the maxima and minima of solar radiation precede those of faculae. One of the diagrams, published in a paper "On Solar Faculae and Solar Constant Variations," read last year before the National Academy of Science,[6] may be reproduced anew as an example of unmistakable correlation (fig. 1).

Here, on the curves for the month of October, November, and December, 1929, we see that not only the maxima and minima of both curves correspond to each other, but also that characteristic interruptions in the trend may be observed, as could only happen in case of cause and effect. On figure 1 the upward trend T_1 repeats itself in T_2 and T_3, after the ruptures R_1 and R_2 and the well-pronounced maxima $M \odot C^t$ and Mf display perfectly the cause and its effect belated by 2 days. It seems evident that some unsatisfactory solar-constant values may be the cause of the curves not being more alike than they are.

The type of variation reproduced on the above diagram is very far from being general. We can distinguish different types of variation and, frequently, characteristic discontinuities between these types. For example the curve of the faculae observed during the months March

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[2] Ann. Astrophys. Obs. Smithsonian Inst., vol. 5, p. 279, 1932.

[3] Results of measures made . . . . of photographs of the sun at Greenwich, the Cape and Kodaikanal in the year . . . .

[4] H. H. Clayton, making use of the figures for 1918-1921, found a marked maximum of solar radiation on the day of the maximum of faculae (Smithsonian Misc. Coll., vol. 77, No. 6, p. 53, 1925).

[5] The faculae are expressed in millions of the solar disk and corrected for foreshortening.

[6] Arctowski, Henryk. Proc. Nat. Acad. Sci., vol. 26, No. 6, pp. 406-411, June 1940.

to November, 1935, may be divided into three parts: March 6 to May 10, May 14 to July 28, and July 30 to October 2.

The first section of this curve (fig. 2, A) displays a more or less regular superposition of two variations of about 12 days' duration each. The maxima of one correspond to the minima of the other. Therefore a maximum occurs approximately every sixth day. The superposition of the two variations is not quite perfect. The maximum of March 9 on curve *a* is cut off, while the maximum of March 14 on curve *b* is perfectly regular. On March 20 there is a secondary minimum *b′* in the place of the maximum *a*, and March 25 we observe the minimum *a′* instead of the maximum *b*.

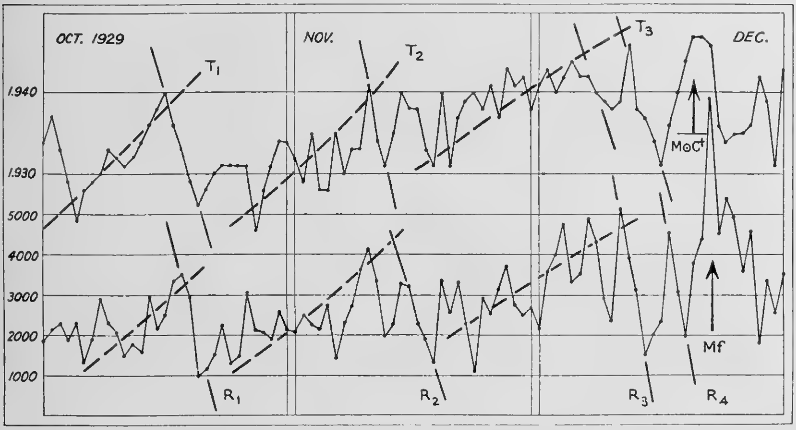

FIG. 1.—Solar-constant values for October, November, December, 1929, and areas of solar faculae, expressed in millionths of the sun's visible hemisphere.

Since only the maxima of March 14, April 1, 5, 11, and 17 are well developed, the coexistence of the variations *a′* and *b′* should be admitted.

After April 19, curve *a* shows increasing maxima of the areas of faculae, and instead of curve *b*, which ceases to play any role, the minima of *b′* are shifted far up, affecting the maxima of curve *a*.

Between May 10 and 14 we notice a break. From then on we pass to a different kind of variation (fig. 2, B). The maxima are now 9 or 10 days apart, they increase until July 5, and, with the exception of the two first maxima, they are well developed.

Between curves A and B no faculae were observed on May 14. The same applies to July 29 marking the beginning of curve C. This last type of variation differs radically from those of curves A and B. Now there is a broken tendency of increase—a series of inclined steps leading toward a very much sunken maximum. The data of October 1 to 19 may be considered as belonging to the maximum. The breaks between the steps of uplift occur from August 15 to 17, 26 to 28, September 11 to 13 and 28 to 30. After the maxima of the first part of October, three opposite steps of decreasing tendency, characterized by breaks of downfall, are observed from October 25 to 29, November 6 to 11 and 18 to 20. There is a certain similarity between this type

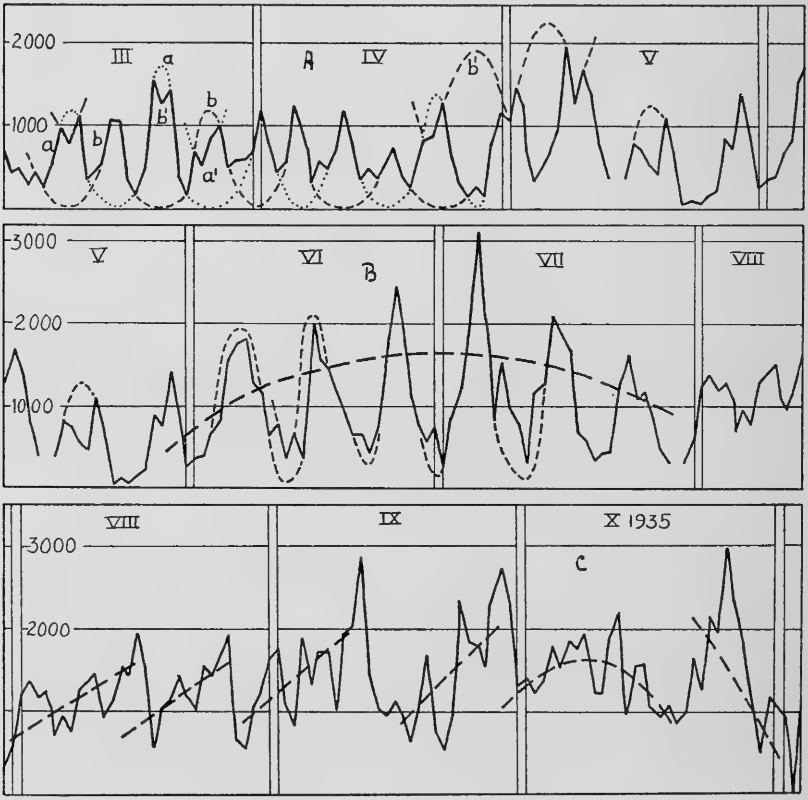

FIG. 2.—Daily areas of faculae for March to October, 1935.

of variation and the so-called "points of symmetry" of the curves of meteorological phenomena, particularly of the breaks in the annual variations of pressure and temperature, studied years ago by Deville.[7]

[7] Deville, Ch. Sainte-Claire, Des perturbations périodiques de la température dans les mois de février, mai, août et novembre. C. R. Acad. Sci., vol. 61, pp. 5-11, 1865; Sur les variations périodiques de la température dans les mois de février, mai, août et novembre. Ibid., vol. 63, pp. 1030-1038, 1866; Sur la périodicité des grands mouvements de l'atmosphère. Ibid., vol. 81, pp. 921-925, 1875.

Coming back to the 6- or 7-day mean duration of the well-pronounced maxima or minima of the solar-constant data, the types A, B, and C of the variations of the areas of faculae, observed during the year 1935, show very plainly that means may be misleading. One should not combine the maxima or the minima of different types of variations such as A, B, and C. It is always advantageous to compare individual maxima or minima, but the unavoidable errors of solar-constant measurements make individual features uncertain. A new method introduced in July 1941 by Dr. Abbot may give greater certainty to individual solar observations.

A correlation of the types of variations of faculae and of solar-constant daily data is most probable, and the quasi coincidence of occurrence of individual maxima and minima is certain. But the solar constant undergoes variations during years of sunspot minima, when there are frequently long successions of days with no observed faculae. This leads to the conclusion that the faculae are not the cause but simply an indicator of the intensity variations of solar radiation.

As the maxima of the extent of faculae usually occur 1 or 2 days after the dates of the solar-constant maxima, we must conclude that they are the effect of the same changes as those governing the variations in intensity of solar radiation instead of being their cause.

2. TEMPERATURE CHANGES

The diagrams of daily observed temperatures, or the variations registered by thermographs, show the existence of more or less regular waves. Such "6- or 7-day weather periodicities" or "rhythms in the weather" have been studied by Clayton[8] and many other meteorologists. However, the analogy of the $6\frac{1}{2}$- or 7-day periodicity with that of the mean duration of characteristic solar-constant maxima and minima is evidently only accidental. The variations of the rhythms of the extent of faculae as shown in figure 2 demonstrate this fact. The same applies to atmospheric waves. Extensive studies have been made of them. A short summary of results will be given in the following paragraph.

Mean temperature changes for the same 72 and 82 series of dates made use of above have been compared with the solar-constant variations in a paper read at the Washington meeting of the American Meteorological Society, April 25, 1940.[9]

[8] Clayton, H. Helm, Six and seven day weather periodicities. Amer. Meteorol. Journ., vol. 1, No. 1, pp. 35-44, 322-325, May 1893; Rhythm in the weather. Ibid., vol. 11, No. 10, pp. 376-380, Feb. 1895.

[9] Arctowski, Henryk, Researches on temperature changes from day to day and solar constant variations. Bull. Amer. Meteorol. Soc., vol. 21, No. 6, pp. 257-261, 1940.

At Kew Observatory, near London, the maximum of temperature occurs 1 day later than the mean maximum of the constant values. But a second maximum, 4 days later, is more pronounced than the first. For the mean temperatures corresponding to the minimum of solar constants there are also two minima: a direct minimum, less than 1 day after the minimum of mean solar-constant values, and another belated, indirect, well-pronounced minimum.

The same is true in New York City, except that the maximum is slightly in advance whereas the minimum corresponds exactly with the solar-constant minimum. However, in New York City this direct minimum is the principal minimum, while the minimum of the fourth day after, the indirect minimum, is only slightly accentuated. The same applies to the curve corresponding to the solar-constant maximum.

At Prince Albert, Canada, the indirect maximum occurs 6 days later than the one corresponding to the maximum of solar constant. There the curve of the minimum seems to display an uplift of the mean temperatures for the days 0 to +3 and a very belated secondary minimum.

The curves of Port-au-Prince (Haiti), Campos Rodriques (Mozambique), and San Bartolomé (near Bogota, Colombia) were compared next. The Campos Rodriques minimum curve is very like that of New York City, if we shift it 2 days to the left. In one case the means of the days −2 to +3 seem to be uplifted, in the other case it is those for days 0 to +5.

Such comparisons of stations show that we must not only distinguish the direct and indirect or belated influence of the solar-constant variation upon temperatures, but also note that secondary minima may be due to an uplift of the principal minimum. Therefore, such curves of mean values might lead to wrong interpretations and should only be used as indicators of what to look for while comparing the curves of temperatures corresponding to individual ups and downs of solar-constant values.

Comparisons of the curves for alpine observatories on the Sonnblick, the Saentis, and the Obir (altitudes, 3,106, 2,500, and 2,044 m.) have shown that, on the Sonnblick, the direct effect of a solar-constant maximum is felt on the date of the maximum, 1 day later on the summit of the Saentis, 600 m. lower, and 2 days later on the Obir, 500 m. below the Saentis.

This leads to the necessity of making use of upper-air data in order to locate the regions of direct hits in our atmosphere.

In a lecture on "The Illusions of the Upper Air," as long ago as 1916, Sir Napier Shaw said: "The stratosphere is the operator and the lower air the subject operated on." Already, in 1916, if not even before the date of Shaw's lecture, there were indications that the variations of solar radiation [10] make the stratospheric "operator" work.

Taking into consideration individual cases of maxima or minima, instead of mean values, the example of the temperatures observed at Verkhoïansk in northern Siberia, at the pole of cold, will be

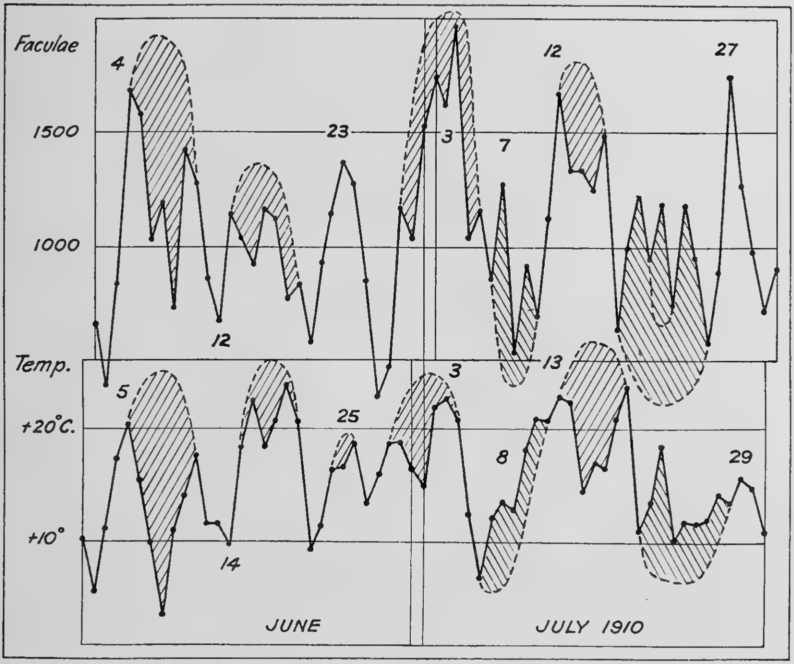

FIG. 3.—Faculae and daily temperatures at Verkhoïansk, June and July, 1910.

sufficient to show that there must be regions of direct hit, not necessarily high up but at the bottom of the atmosphere as well. The curves of areas of faculae, and of daily mean temperatures observed at Verkhoïansk, during the months of June and July, 1910, are so similar (fig. 3) that there can be no doubt that they have a common cause of variation.

[10] "The solar-constant observations at Mount Wilson in the years 1905 and 1906 had seemed to indicate a fluctuation of the solar radiation, having an irregular period of 7 to 10 days, and of an irregular range of 2 to 8 per cent." Ann. Astrophys. Obs. Smithsonian Inst., vol. 3, p. 117, 1913.

Taking into account the time difference between Greenwich and 133° E., the longitude of Verkhoïansk, it is obvious that the maxima of June 4 and 5 are practically simultaneous. The same may be said of those of July 3 and 12-13. But, since in most cases there is a tendency toward more than a day's difference in time, the temperature curve had to be slightly shifted to the left in order to show the similarity of both variations.

If, during the year 1910, the maxima and minima of faculae occurred 1 or 2 days after those of the solar constant, as we found in recent years, there should also be a difference of 2 or 3 days between the solar cause and the temperature effect, as appears for the temperatures observed during January 1910, with mean temperatures ranging between $-31°$ and $-57°$ C.

The latitude of Verkhoïansk is 67°33′ N. In the case of January temperatures when the sun is invisible there, a direct effect of solar variation seems therefore to be excluded. To find the location of origin of temperature waves, maps of isallotherms had to be drawn. The maps for January 1910 will be discussed in a later paper.

For the present a few remarks concerning the difficulties of the problem of temperature changes and their cause may not be out of place.[11]

3. ATMOSPHERIC PRESSURE WAVES

Similar effects of a solar-radiation maximum of a particular day on atmospheric temperatures could not possibly be observed simultaneously all over the world, simply because any change of tempera-

[11] Independently, C. G. Abbot, H. H. Clayton, and the author have been led to admit that the changes of solar radiation from day to day are the prime factor of weather changes. C. G. Abbot has summarized his researches on "The variations of the sun and the weather" in six lectures recently delivered at Harvard College Observatory (see Bull. Amer. Meteorol. Soc., vol. 21, p. 407, December 1940). In addition, Abbot's papers published in the Smithsonian Misc. Coll., vol. 77, No. 5, 1925, vol. 85, No. 1, 1931, vol. 95, No. 12, 1936, and vol. 101, No. 1, 1941, should be read, as well as a paper "On the influence of solar variability on the weather," published in the Scientific Monthly, August 1936.

The most important contributions of H. Helm Clayton on solar-constant data and weather changes were published in the Smithsonian Misc. Coll., vol. 68, No. 3, 1917, vol. 71, No. 3, 1920, vol. 77, No. 6, 1925, vol. 78, No. 4, 1926, and vol. 89, No. 15, 1934.

The author's first research on "The solar constant and the variations of atmospheric temperature at Arequipa and some other stations," was published in 1912 (Bull. Amer. Geogr. Soc., vol. 44, p. 598, 1912). His paper on the role of the stratosphere in climatic variations, published in 1934 (Inst. Geof. i. Meteorol., Uniw. Lwów, Kom., vol. 7, No. 85, pp. 193-226) was an introduction to his present researches.

ture affects the distribution of atmospheric pressure and the pressure gradients. Continental and oceanic areas will react differently to the same radiation changes and the distribution of the different cloud levels and of cloudiness must produce regional differences in the action of any solar impulse. Besides, pressure changes will affect wind directions and the transport of air masses, and therefore the distribution of temperature, at and above the earth's surface.

It would all still be simple and more or less regular and the solar-constant maxima would perhaps always affect the centers of action of atmospheric circulation in the same way if they remained localized as indicated on climatological maps. But these centers of mean high and low pressure move with the changes in the general atmospheric circulation from south to north or from east to west. All changes proceed by waves or groups of waves.

The paths of cyclonic or anticyclonic centers are variable. It is possible that these paths are greatly influenced by atmospheric waves. More than that: even the formation of lows and highs of pressure, their tracks and their changes in form and extent, may be directly produced by atmospheric waves.

The pressure waves of an amplitude exceeding 5 mm., recorded by a barograph during the months of March 1898 to March 1899, on board the *Belgica,* in the Antarctic pack ice, gave a mean duration of 5 days and 6 hours from one maximum to the following one.[12]

A most interesting table of figures, compiled by Simpson[13] leads to a far-reaching hypothesis. The figures giving the mean duration of Antarctic waves are:

	Latitude, S.	Mean duration, hours
Kerguelen	49°	69
South Orkneys	61°	91
Snow Hill	64°	107
Gauss Station	66°	122
Belgica Station	70°	126
Cape Adare	71°	119
McMurdo Sound	78°	152
Framheim	79°	163

These figures show that the waves are twice as long in latitude 78° S. as in 50° S. This fact leads to the hypothesis that most probably the pressure changes observed on Kerguelen Island are the

[12] Arctowski, H., Résultats du voyage du S. Y. Belgica . . . . Rapport sur les observations météorologiques horaires, p. 26. Anvers, 1904.

[13] Simpson, G. C., British Antarctic Expedition 1910-13. Meteorology, vol. 1, p. 188. Calcutta, 1919.

product of two intercrossing systems of waves, one of them originating on the Antarctic continent.

The mean duration of the longest waves, those of Framheim, correspond to the $6\frac{1}{2}$ or 7 days of the solar-constant variations noted during the years 1926 to 1930.

The reception of pressure waves on the earth's surface, arriving simultaneously from different points of origin, possibly from the centers of lowest and highest temperatures for example, renders the search for a direct correlation with solar phenomena extremely difficult.

Periodicities, if any, may differ even if all variations are due to only one cause. Simultaneity of maxima or minima is excluded, in general, but not always. Finally, the changes of atmospheric pressure, of course never simultaneously in plus or minus all over the world,

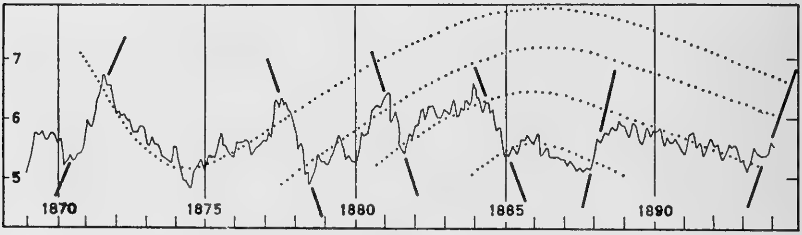

FIG. 4.—Pressure wave-length variation in Warsaw. Consecutive monthly means.

even if exclusively due to temperature anomalies originally produced by solar-radiation anomalies, must in turn affect wind direction and therefore temperature changes.

Taking a particular station one may study the changes of pressure wave lengths.

The monthly numbers of waves, of an amplitude of 5 mm. or more, observed at Warsaw, Poland, during the years 1870 to 1894 have been tabulated by Merecki.[14] Making use of his figures, overlapping 12-monthly means gave the diagram of figure 4. The lowest and highest means are 4.8 and 6.7 days—a difference similar to that between Snow Hill and McMurdo Sound, or latitudes 64° and 78° S.

No simultaneity all over the world of such changes in the length of pressure waves can be expected, except perhaps if it were possible to consider exclusively the centers of origin. Even there, at the centers of origin, admitting a direct effect of solar changes, such as are shown on figure 2 for the extent of faculae, the length of duration

[14] Merecki, R., Klimatologja ziem polskich, p. 200. Warszawa, 1914.

of the waves should differ from time to time, just as it does in the case of solar phenomena.

The centers of origin are not necessarily the centers of action of Teisserenc de Bort. The areas of high pressure of the Azores and low pressure of Iceland, as well as other centers of action, relate to atmospheric pressure at the earth's surface and of the lower troposphere only. This leads to the hypothesis that the centers of origin of the pressure waves should be high up. Because it is only if they are connected with the temperature changes observed in the upper troposphere or in the stratosphere that it will appear perfectly comprehensible why the distribution of the waves and their paths of displacement may be independent of the so-called centers of action, and to a certain extent also independent of the lows and highs of the weather maps.

Let us go back to the diagrams of the pressure waves observed at Warsaw. Characteristic breaks counteract a tendency toward excessive variation. The minimum of the years 1872-1878 is uplifted, whereas the maximum of 1887 is very much lower than it should have been. Besides, between the breaks, the curve proceeds by steps of smaller oscillations. An analogy with the breaks between parts A, B, C of figure 2 is obvious.

Taking 10-day overlapping means of pressure observed from March 1902 to February 1903 Simpson found variations which he called surges. His figures are:

	Latitude	Longitude	Duration, days
Hut Point	71°51′ S.	166°45′ E.	35
Gauss	66° 2′ "	89°38′ "	42
Snow Hill	64°22′ "	57° 0′ W.	39
Kerguelen	49°25′ "	69°53′ E.	37
Greenwich	51°28′ N.	0° 0′	37
Irkoutsk	52°16′ "	104°19′ E.	51
Stykkisholm	65° 5′ "	22°46′ W.	28
Vardö	70°22′ "	31° 8′ E.	34

These surges of Simpson's are nothing other than brachypleions [15] such for example as those of the 10-day overlapping means of pressure observed at Batavia during 1916-1917.[16] The diagram (fig. 5) shows that there, under the Tropics, the breaks of the annual variation,

[15] Arctowski, Henryk, The pleonian cycle of climatic fluctuations. Proc. Second Pan American Sci. Congr., vol. 2, p. 172.

[16] Arctowski, Henryk, and Teśla, J., Étude des transports de masses atmosphériques survenus au cours du mois de Mars 1931. Inst. Geof. i. Meteorol., Uniw. Lwów, Kom., vol. 8, No. 101, p. 176, 1936.

the cause of the brachypleions, should be considered as an overlapping of two opposite tendencies: in July-August minimum of pressure in Asia, maximum in Australia, and in January-February the opposite —in other words, steps of ascent and descent due to action and reaction of one continent and the other.

This diagram is an illustration of the rhythm of the transport of air masses in the course of the year from one hemisphere to the other and back again. All is due to excess of heating and cooling of the atmospheric bottom.

The same should apply to the transport of air masses from continental to oceanic areas during the winter and from the oceans to the continental minima of pressure during the summer. And, in the case of the Antarctic continent, from south to north in both summer and

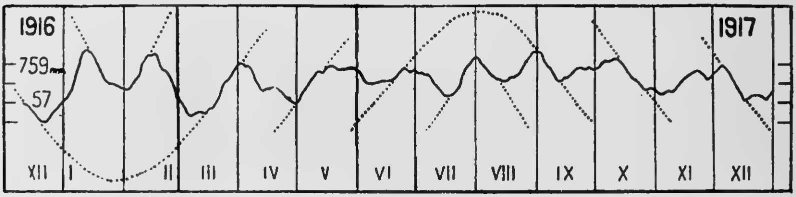

Fig. 5.—Pressure brachypleions, Batavia, 1917.

winter, but with a great change in the character of the waves: at McMurdo Sound (77°38′ S., 66°30′ E.), for example, brachypleions of 39 days' duration from October to March and of 52 days' duration during the months of the Antarctic winter.

4. BAROTERONS AND THERMOTERONS

For many years maps of isallotherms and isallobars, representing the distribution of temperature and pressure changes from day to day, have been made use of by weather forecasters.

It is obvious that in order to facilitate discussion of the appearance and movement of areas of falling and areas of rising pressure a single word be provided for them. This need has been anticipated by Dr. N. Ekholm . . . . Ekholm proposes and uses in the sense given the following terms:

Allobar: an area of pressure change,

Anallobar: an area over which pressure has risen,

Katallobar: an area over which pressure has fallen.[17]

[17] Henry, Alfred J., Auxiliary pressure-change charts. U. S. Weather Bur., Weather Forecasting in the United States, W. B. No. 583, chap 4, p. 79, 1916.

It was in 1913 that Ekholm proposed these terms in the Publication de Circonstance No. 64 of the Conseil Permanent International pour l'exploration de la mer. In others of his well-known papers, on maps of isallobars, Ekholm has made no use of these terms.

Not knowing of the above citation, nor having come across these terms in Ekholm's papers the writer stated in 1939:[18]

I have proposed to apply the term anoterons to areas of positive pressure differences observed from day to day at a given hour, and katoterons to those of pressure decrease. A pressure wave may therefore be called a teron or a baroteron. And a wave of temperature: thermoteron.

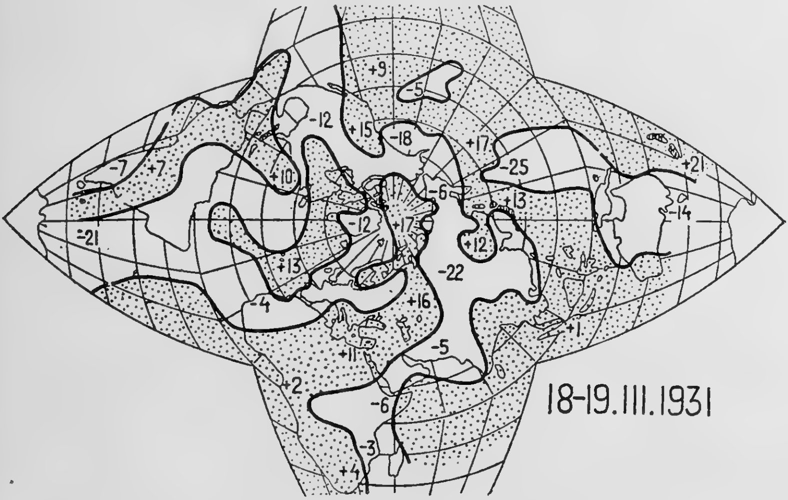

FIG. 6.—Baroterons. Differences of pressure from day to day.

Maps of isallobars for western Europe have been published regularly in the daily weather reports of the Office Météorologique de France. On these maps the most essential fact concerning terons has evidently been ignored. This fact is that the terons may extend from Pole to Pole, across the Equator.

The map of March 19, 1931, reproduced above (fig. 6), does not represent an exceptional case—far from it. To make sure that the tropical regions do not play a passive role, all obtainable data for the Sunda Islands for the month of March 1931 were used to connect the Australian maps with those of eastern Asia. The isallobaric maps thus drawn leave no doubt concerning the mutual dependence of the pressure changes observed north and south of the Equator. But

[18] Arctowski, Henryk, On weather changes from day to day. Monthly Weather Rev., vol. 67, No. 9 (W. B. No. 1277), pp. 322-330, 1939.

bipolar baroterons may be interrupted by crossings of other pressure waves.

Detailed maps of pressure and temperature changes observed from day to day during January 1910 in Europe, North Africa, Siberia, and India show that intercrossings are the rule.

A thermoteron may extend from Turkestan across the Pamir and the Himalaya Mountains. This fact shows that occasionally, if not always, the changes observed at the earth's surface belong to changes occurring high above an altitude of 4,000 m.

Finally, if we compare the pressure changes that have occurred simultaneously at different stations, not even very far apart, we are

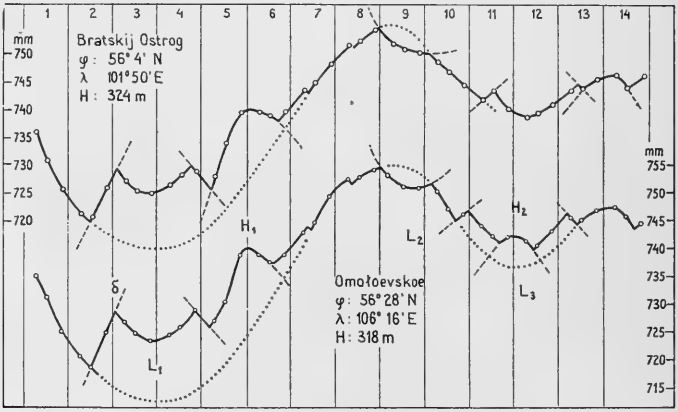

FIG. 7.—Pressure waves in Siberia, January 1-14, 1910.

led to the opinion that they are due to superpositions of variations of different wave lengths and to the effects of action and reaction of opposite variations.

One example will be sufficient to show a simple case of such complications of pressure changes. At Omoloevskoe (fig. 7) we distinguish the wave L_1 L_2 L_3 from the wave H_1 H_2 (wave length of 8 days for the former, 6 days for the latter). A reaction δ uplifted the minimum L_1; another reaction affected the maximum L_2. Discontinuities of variation, such as δ, are the rule.

All ups and downs of the barometer are the effect of distinct baroterons, extending north-south and east-west for example, and moving west-east and north-south or in other directions. The coexistence of different directions of transport of air masses, the intercrossing, leads to the hypothesis that they may belong to different levels of our atmosphere—one system high above, another down below.

If this is so, it seems obvious that nothing can be explained without taking upper-air data into account. Besides, since the changes of pressure from day to day are insignificant under the Equator, if compared to those of higher latitudes, it is obvious that counting the number of waves of more than 5 mm. of amplitude will lead to figures not necessarily comparable.

Only maps of isallobars and the diagrams of pressure variations (such as those in fig. 7) will give the possibility of identifying the superposed waves.

All changes of pressure must be primarily due to changes of temperature distribution. Are distinct differences observed between temperature changes at different levels? Such is the first question to be answered in the study of the effects of solar-constant variations.

5. THE AMERICAN RADIOMETEOROGRAPH OBSERVATIONS

Since July 1939 daily night radio soundings have been most successfully carried on at a number of stations in the United States, Alaska, the West Indies, and at two floating Atlantic stations. The monthly means of these observations are published in the Monthly Weather Review. For the months July 1939 to February 1940 photostat copies of the manuscript tables of daily observations were obtained from the Weather Bureau.

These data have been compared with the Smithsonian solar-constant observations of the Montezuma Station in Chile. A characteristic maximum of the solar constant was observed at Montezuma on July 4, 1939. The figures are (calories):

July 2	3	4	5
1.938	1.941	1.944	1.935

They correspond to the morning hours of these dates.

The full effect of the maximum of the 4th upon the American aerological night soundings should be observed on the 5th. The temperature data for Oakland, Calif., are (degrees C.):

	July 3	4	5	6
Surface	12.5	15.5	14.6	14.2
Altitude 5 km.	— 2.6	— 7.0	— 6.4	— 3.0
Altitude 16 km.	—65.0	—60.0	—61.0	—69.0

These figures seem to indicate a direct effect at the earth's surface and at an altitude of 16 km., while between, at an altitude of 5 km. in particular, the variation in the figures is just the reverse of what it should be. Such however is not the general rule.

A maximum of the solar constant has been observed on August 11. The figures are (calories):

August 9	10	11	12
1.922	1.930	1.935	1.924

But the last observation was not "very satisfactory."

The maximum of the 11th should be observed in the temperature data of the 12th. Some characteristic figures for Sault Ste. Marie, Mich., for August 10 to 13 are reproduced below (degrees C.):

	August 10	11	12	13
Surface	15.7	14.2	17.7	13.3
Altitude 5 km.	— 9.2	— 6.8	— 5.6	— 9.3
Altitude 11 km.	— 51.0	— 49.0	— 47.1	— 51.3
Altitude 13 km.	— 55.3	— 61.7	— 60.4	— 53.1

These figures show a direct effect up to 11 km., the reverse at altitudes of 13, 14, 15 km.

At Nashville, Tenn., the maximum was observed on the 12th at altitudes of 16 to 18 km., whereas it was retarded by 1 day from 5 to 14 km.

At Phoenix, Ariz., there was a slightly pronounced maximum on the 12th from 5 to 14 km., but the figures were perfectly characteristic at 18 and 19 km.

At Atlanta, Ga., a maximum was observed on August 11th at the altitude of 18 and 19 km. At 16 km. there is a tendency of opposition.

At Denver, Colo., a perfect maximum occurred on the 12th at 10 km. and on down to 3 km. The following day, the 13th, a maximum was observed at the earth's surface and at altitudes of 12 to 14 km.

At El Paso, Tex., the figures show a direct effect on the 12th at altitudes of 16 and 17 km., the opposite at 14 and 15 km.

Other similar coincidences could be mentioned.

6. THE EQUATORIAL TROPOSPHERE

The facts cited above, on the different levels at which a direct response to the solar-constant maximum of August 11, 1939, was observed in the United States, might possibly have been due to accidental coincidences. Air masses should be taken into consideration, and then perhaps all could be explained without the necessity of admitting any atmospheric response to changes of solar radiation.

Annual variations should serve as an approach to the study of what might occur under the influence of solar changes from day to day. In the course of the year the length of the day changes as well as the elevation of the sun above the horizon. Seasonal variations of temperature should therefore exist high above as well as at the earth's surface.

A minimum of difference, or, high up, even no difference at all, between summer and winter should be observed in the Tropics. Is it so over Batavia, 6° S. of the Equator? The highest and lowest 2-monthly means of 63 soundings, made during the years 1910 to 1915 are:[19]

Table 1.—*Mean temperatures and differences at Batavia*

Altitude		Altitude	
8 m......	26.8 ≷ 25.8 = 1.0 °C.	9 km.....	−29.3 ≷ −24.0 = 5.3 °C.
1 km.....	21.1 “ 20.0 = 1.1 “	10 km.....	−38.2 “ −32.6 = 5.6 “
2 km.....	16.1 “ 14.3 = 1.8 “	11 km.....	−46.6 “ −40.5 = 6.1 “
3 km.....	10.5 “ 9.0 = 1.5 “	12 km.....	−54.8 “ −49.3 = 5.5 “
4 km.....	5.1 “ 3.9 = 1.2 “	13 km.....	−62.5 “ −57.5 = 5.0 “
5 km.....	−2.4 “ −0.4 = 2.0 “	14 km.....	−70.7 “ −64.9 = 5.8 “
6 km.....	−8.6 “ −5.5 = 3.1 “	15 km.....	−76.8 “ −71.3 = 5.5 “
7 km.....	−14.6 “ −11.0 = 3.6 “	16 km.....	−81.2 “ −75.5 = 5.7 “
8 km.....	−21.5 “ −17.3 = 4.2 “	17 km.....	−85.5 “ −78.7 = 6.8 “

The differences increase from 4 to 11 km. and again above 13 or 14 km. The greatest difference was observed at an altitude of 17 km., still beneath the tropopause.

It is above the level of the lower clouds that the differences increase steadily with altitude. The second increase, above 15 km., corresponds to levels where the highest *Ci* clouds are observed only exceptionally. And it is there that the amplitude is greatest.

Step by step, going up, the type of annual variation changes. At an altitude of 11 km. (fig. 8) the minimum of July-August is predominant. This is the minimum of the Antarctic winter. From 13 km. up, the character of the annual variation changes gradually toward the Asiatic type observed at 17 km., perhaps still more perfectly higher up. A comparison of the diagrams leads to the hypothesis that Asiatic continentality affects temperature up to an altitude of at least 17 km., or the entire troposphere of equatorial regions, and that this continental influence extends into the Southern Hemisphere, even farther than 6° S.

Another purely hypothetical conclusion would be that we might expect an important annual variation of the altitude of the tropopause,

[19] Wagner, A., Klimatologie der freien Atmosphäre. Handb. Klimatol. (Köppen und Geiger), vol. 1, Teil F, p. F43, 1931.

depending on continentality, and that in central Asia the troposphere extends, at least during the summer months, up to an altitude of 17 km.

A comparison of the temperature curves for Batavia, those for the months March-April and September-October in particular, leads to another question which should be answered. The curves (fig. 9) show that the march of decrease of temperature with altitude changes

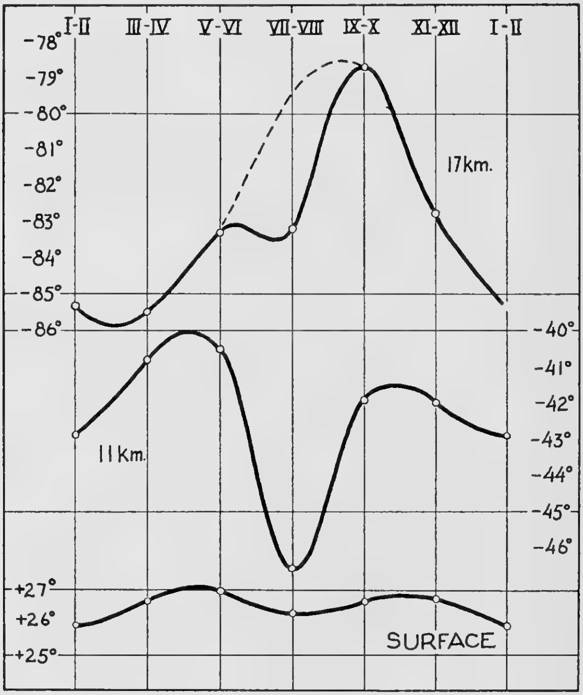

Fig. 8.—Annual variations of temperature, Batavia.

above 15 km., and that the annual variation at an altitude of 17 km. must be primarily due to a change of lapse rates above 14 or 15 km.

The following table gives the lapse rates.

Table 2.—*Lapse rates, Batavia*

	Altitude, km.								
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9
III-IV	5.8	5.5	5.5	5.5	5.4	5.5	5.2	6.3	6.8
IX-X	6.0	5.7	5.6	5.0	5.8	5.8	5.2	6.6	6.6

	Altitude, km.								
	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18
III-IV	7.6	8.2	8.5	8.2	8.4	8.6	6.2	4.8	0.1
IX-X	8.2	7.9	8.6	7.8	6.6	6.4	4.2	3.2	..

We see that in September-October up to an altitude of 7 km. temperature is only 5° or 6° lower per 1,000 m. in altitude. Then, from 7 to 12 km. there is a steady increase, followed higher up by a regular decrease. The data for the means of March-April are similar up to 12 km., and the decrease above begins 3 km. higher up, with the difference between 15 and 16 km.

The trade winds bring to the Tropics air masses which must ascend. If, in equatorial regions, the temperature decrease extends to very high altitudes, it may be that it is to these predominantly ascending

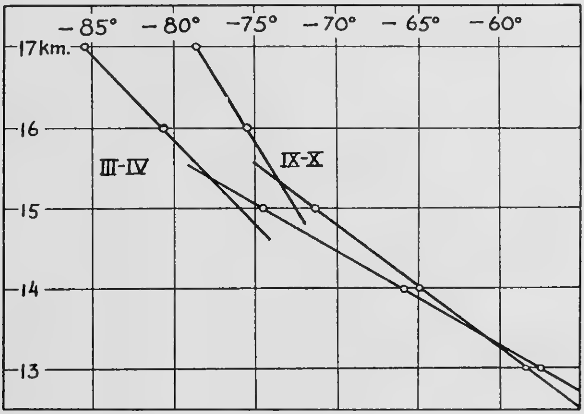

FIG. 9.—Altitude temperature decrease, Batavia.

air currents that we should ascribe the very low temperatures at the tropopause, and the high elevation to which the temperature decrease is observed. If so, and if the beginning of the increase of lapse rates at an altitude of 7 km. corresponds to the horizons of *Al-Cu* clouds and the 12 or 15 km. to those of the highest *Ci* clouds, the decreasing lapse rates above these levels should be of particular significance.

It may be also that the differences in altitude of the limit of the increasing lapse rates are due to stratospheric changes, caused by excess or deficiency of solar radiation, in the course of the year and from day to day as well. Admitting that this might be so, any further research on the effects of solar-constant changes will require a study of how the stratosphere may react to solar variations and in turn act upon the troposphere.

The fact that we observe a greater amplitude of the annual variation at an altitude of 11 km., and that going down from there the amplitudes decrease, does not necessarily prove that the seasonal effect originates high above the level of the *Al-Cu* and *Al-Str* clouds. It would be so only in case the opposite variation, at an altitude above

17 km., and of greater amplitude than that observed at 11 km., should not be considered the active factor.

An increase of altitude of the tropopause may produce opposite variations.

If we exclude a possible Asiatic influence, acting beyond the Equator, the reason for the seasonal temperature changes in tropical regions should be sought in the stratosphere high above the cloud-level horizons. It follows that, under the Equator, two equinoxial maxima should be observed. Since this is not the case, an Asiatic continental influence remains more probable.

7. STRATOSPHERE AND PSEUDO-STRATOSPHERE

Summarizing the results of his researches on the thermic structure of the stratosphere, up to 30 km., Jaumotte [20] has been led to admit 18 km. (and in some cases as much as 25 km.) as the base level of the real stratosphere. That would be the atmosphere above the inversion observed in tropical regions. In temperate and polar climates a pseudo-stratosphere, according to Jaumotte, extends from the tropopause of the troposphere up to the real stratosphere of high altitudes. The level of 18 km. or more corresponds also, according to Jaumotte, to the level of increase of helium, of ozone, and of the electric conductivity of the air.

Leaving far-reaching explanations aside, let us examine the results of the American radio soundings, first of all, simply to show that in our latitudes we really must admit the existence of two stratospheres.

One of them, the real stratosphere of Jaumotte, belongs to equatorial regions, the other, the pseudo-stratosphere belongs to high latitudes. The tropopauses of both may be coexistent, and this fact leads to the important conclusion that some of the prevailing theoretical views on the general atmospheric circulation should be radically modified. In particular, the cross-section Equator-Pole, giving the distribution of upper-air temperatures and the general descent of the tropopause toward the Pole, should be changed into a dovetail diagram of a polar tropopause which extends south and dies away under a tropical tropopause which slopes down toward middle latitudes and completely disappears under high latitudes.

This fact is demonstrated by the following diagram (fig. 10) of mean temperatures of several American stations for July 1940 and of

[20] Jaumotte, J., Structure thermique de la stratosphère jusqu'à 30 km. Beitr. Geophys., vol. 50, Nos. 2-4, pp. 403-422, 1937.

the mean annual data for Batavia, as well as the curve of the observations made by Berson[21] on the Victoria Nyanza, in equatorial Africa.

At Batavia, we notice a steady decrease of temperature up to an altitude of 14 km. Then the curve is broken, the lapse rates diminish, and the tropopause is above 18 km. The data for Victoria Nyanza show that there the tropopause must be above 19 km. Breaks in the curve occur at 13 and between 16 and 17 km.

An altitude of 18 km. or more corresponds to the base of the stratosphere as defined by Jaumotte. But the breaks are also significant. They correspond to the altitude of the tropopause at Miami, and to a change of the lapse rates at the altitude of 13 km.

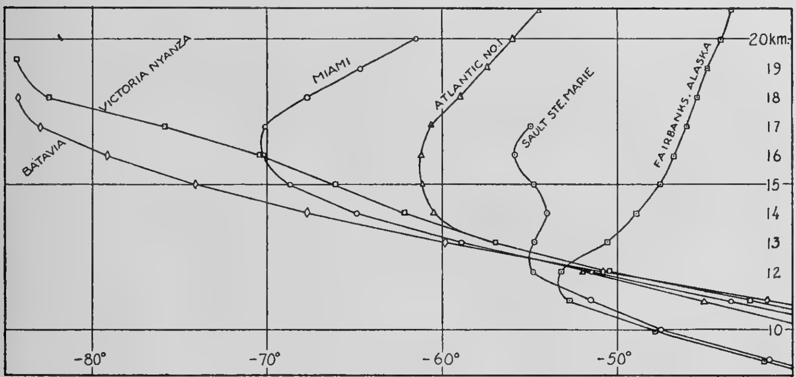

FIG. 10.—Altitude extent of the troposphere. Upper and lower tropopause at Sault Ste. Marie.

The same on the Atlantic, but there the tropopause is nearly 1,000 m. lower than over Miami. The Sault Ste. Marie curve is very different: a break between 9 and 10 km., a tropopause at 12 km., and a second tropopause at 16 km. This last tropopause corresponds to that of Miami. In this case, July 1940, the tropical stratosphere extends to 46° N., coming down from an altitude of 19 or 20 km. to the 17 of Florida and the 16 of the Great Lakes. Much farther north, at Fairbanks, Alaska, the pseudo-stratosphere is the only stratosphere and its tropopause is 1,000 m. lower than at Sault Ste. Marie. The diagram shows that a distinction must really be made between the Arctic and tropical stratospheres, one above 11 km. and the other at 19, that they coexist in the middle latitudes, the tropical above the polar. It is evident that this is an important fact which should be taken into consideration in any theory of atmospheric circulation.

[21] Süring, R., A. Bersons Bericht über die aerologische Expedition des Kgl. Aeronautischen Observatoriums nach Ostafrika im Jahre 1908. Meteorol. Zeitschr., vol. 27, No. 12, p. 537, 1910.

8. THE REVERSAL OF SEASONS IN THE UPPER ATMOSPHERE

Granting that the differences between the mean temperatures of July and January express more or less accurately the amplitudes of the annual variations, Clayton's data have been made use of to draw maps for the United States and Canada.

The highest figures are those for Fort Good Hope (66°15′ N. 128°38′ W.), Hay River (60°51′ N. 115°57′ W.), and Winnipeg (49°53′ N. 97°7′ W.). They are 44°.7, 40°.7 and 37°.3 C. The axis of greatest annual amplitudes crosses the United States from North Dakota down to Texas. The figures for Bismarck and Corpus Christi are 33°.5 and 26°.7 C. West of the axis with the exception of Salt Lake City the figures diminish toward the Pacific coast. The smallest differences are those of Oakland and San Diego respectively.

Taking now the figures for the different altitudes, as they are recorded in the Monthly Weather Review, we see first of all that at San Diego the mean monthly temperatures decrease up to 16 or even 17 km. The troposphere there extends to these high altitudes.

The observations at San Diego for 1940 gave the following results for January, July, and for the months of highest and lowest means of the year:

TABLE 3.—*Mean temperatures at San Diego, Calif.*

Altitude	I	VII	Diff. VII−I	Highest	Lowest	Diff. M−m.
Surface	13.4	18.5	5.1	19.2 VIII	13.4 I	5.8
1 km.	11.4	21.6	10.2	23.3 "	9.4 II	13.9
2 "	6.9	20.0	13.1	21.4 "	4.1 "	17.3
3 "	1.6	13.5	11.9	14.3 "	− 0.2 "	14.5
4 "	− 5.1	6.4	11.5	6.7 "	− 5.8 "	12.5
5 "	−11.9	− 2.9	9.0	− 0.7 "	−12.0 "	11.3
6 "	−18.3	− 9.9	8.4	− 7.0 "	−18.9 "	11.9
7 "	−25.1	−17.1	8.0	−13.5 "	−25.9 "	12.4
8 "	−32.7	−34.6	8.1	−20.7 "	−33.3 "	12.6
9 "	−40.2	−32.7	7.5	−28.5 "	−41.0 III	12.5
10 "	−46.6	−39.8	6.8	−35.6 "	−48.9 "	13.3
11 "	−51.7	−46.9	4.8	−43.1 "	−56.6 "	13.5
12 "	−54.3	−53.8	0.5	−49.5 IX	−61.3 "	11.8
13 "	−56.1	−59.9	− 3.8	−55.7 "	−61.9 III & XI	6.2
14 "	−57.8	−65.2	− 7.4	−57.8 I	−65.2 VII	7.4
15 "	−59.4	−69.6	−10.2	−59.4 "	−69.6 "	10.2
16 "	−62.5	−71.0	− 8.5	−62.2 IV	−71.0 "	8.8

These figures show, first of all, an increase in amplitude of the annual variation up to an altitude of 2,000 m. This increase would have been even greater if a reaction of a reverse variation, dictated from above, had not interfered.

The curves of the annual variations for the surface and for the altitudes of 2, 13, and 16 km., reproduced below (fig. 11), express graphically an interpretation of these two tendencies.

The differences (see table 3), particularly those of highest and lowest means, show another important fact: there are two characteristic tendencies of increase from 5 to 11 km. and from 13 to 15 km. of the maxima minus minima differences.

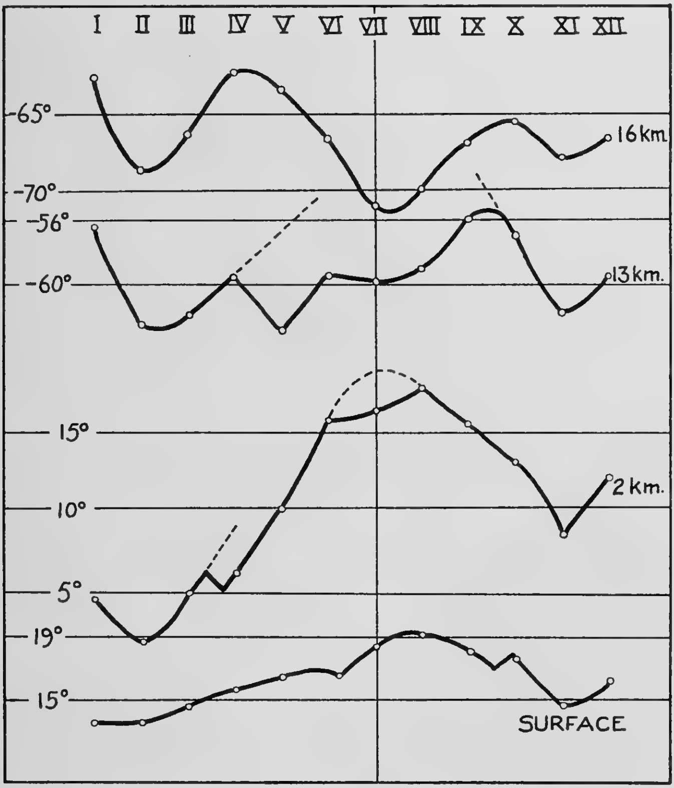

FIG. 11.—Annual variations of temperature, San Diego, Calif., 1940.

This fact is important, because it demonstrates the existence of certain characteristic levels in the troposphere, above which solar radiation acts differently. Frequent fogs and low clouds may be the cause of the exceptionally low figure for the amplitude of the annual variation at sea level and its rapid increase up to an altitude of 2,000 m. The decrease above 2 and up to 5 km. should then be ascribed to the general conditions of decreasing amplitudes with altitude prevailing over the continent.

Then, at an altitude of 5 km. we are above the level of the *Al-Cu* clouds, and from there on the amplitude increases. As for the decrease above 10 or 11 km. and the increase above 13 km., it would be difficult to connect these altitudes with the levels of *Ci* clouds.

It may be that at these elevations the seasonal changes of the general atmospheric circulation are in action. The reversal of the seasons at 16 km., lowest temperature in July and August ($-71^\circ.0$ and $-69^\circ.9$), is most significant. These temperatures are just as low as those found in tropical Africa at the same altitude, where, above the Victoria Nyanza, Berson found a temperature of $-70^\circ.4$, while over Batavia

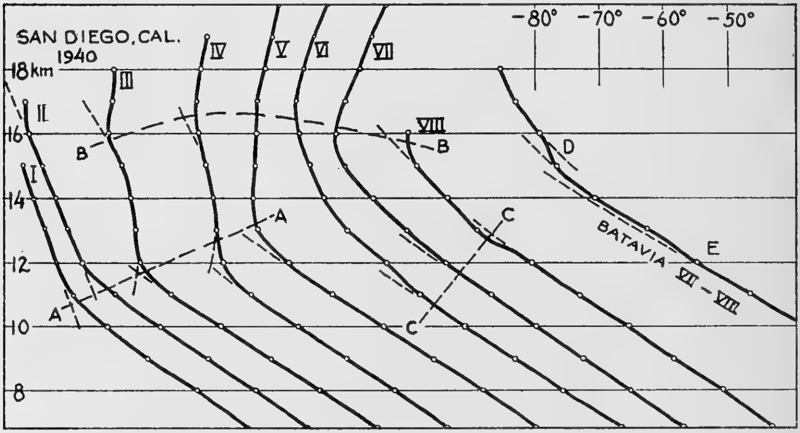

FIG. 12.—Monthly temperature curves, lower and upper inversion, San Diego, Calif.

it was $-79^\circ.2$. Lower temperatures over the Equator is just what should be expected if we believe that the upper inversion of San Diego corresponds to the equatorial inversion, the altitude here being about 3,000 m. lower than at Batavia or the Victoria Nyanza.

For this upper inversion and the existence of a lower inversion during the months of March, April, and May at San Diego, the preceding diagram (fig. 12) of the monthly mean temperatures, observed above 8 km., will help to explain the minimum for July and August.

The curves for January and February show a change of lapse rates above 11 km. The curve for March is the same, but the slightly marked inversion above 12 km. and the second inversion at 16 km. show that the change of lapse rates for January and February corresponds to the lower inversion of March.

On the diagram the line AA indicates the tendency of this inversion to increase in altitude from 11 to 13 km. during the months January to May. In June, July, and August only the upper inversion BB is to be observed together with changes of lapse rates CC. On the curve of Batavia (July+August), the characteristic changes of lapse rates, letters D and E, suggest the idea that there may be some relationship between them and the levels BB and AA of San Diego.

To come back to the differences of July and January (1940) mean temperatures, table 4 gives the necessary data for the drawing of diagrams. A comparison of the figures is sufficient, however. We notice the characteristic increase of amplitude of the annual variation from 4 to 6 km. at Medford, from 5 to 7 at Spokane and Boise, from 6 to 8 at Ely and Phoenix, from 6 to 9 at Denver, Albuquerque, and Oklahoma City. The temperature differences up to 8 or 9 km. from 4, 5, or 6, increase with altitude in the southern States as well as in Nevada, Colorado, Nebraska, and Oklahoma. At Minneapolis and Sault Ste. Marie the increase goes on from 3 to 7 km., at Joliet to 6, and from 4 to 6 at Bismarck, Buffalo, and Lakehurst. The distribution of these figures on the map shows that the important step between the lower and the higher tropopause, marking an interruption in the decrease with altitude of the amplitudes of annual variations, cannot be due to cloud levels. It is the general upper atmospheric circulation which changes with the course of the seasons.

The following maps (fig. 13) giving the geographical distribution of the figures of table 4, for the altitudes of the stations where observations are made and for 2, 7, 11, 12, and 15 km. above sea level, will help in understanding the influence of continentality upon the annual amplitudes in the lower troposphere, and the dominating effect of latitude above 12 km., 15 in particular.

On the last map an axis of the most negative figures extends from Lakehurst over Nashville to Denver and San Diego. At 13 km. also the negative axis extends across the States, from the Atlantic to the Pacific, slightly to the north.

The map for 12 km. shows the beginning of negative values (July lower than January temperatures) and the persistence of high positive differences in Arizona. At 11 km. there are no more negative values: up to that altitude the annual variation is more or less similar to that of the lower troposphere.

On the map for 7 km. the differences higher than those for 6 km. have been underlined.

TABLE 4.—*Mean temperature differences July-January, 1940*

		Altitude, km.														
	Surf.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Seattle, Wash.	12.4	9.7	8.8	8.4	8.8	9.7	...	...	...	...	...	...	...	...	...	...
Medford, Oreg.	18.0	14.5	12.8	14.0	13.7	13.8	14.6	14.5	14.4	13.8	12.2	9.2	4.2	— 1.1	— 0.1	1.9
Oakland, Calif.	6.0	13.5	14.4	13.2	12.8	12.3	12.6	12.1	11.8	11.9	11.5	9.2	4.2	— 0.5	— 1.5	— 0.5
San Diego, Calif.	5.1	10.2	13.1	11.9	11.5	9.0	8.4	8.0	8.1	7.5	6.8	4.8	0.5	— 3.8	— 7.4	— 10.2
Spokane, Wash.	24.1	26.5	22.1	17.9	15.4	15.7	16.0	16.4	15.3	15.5	13.4	9.1	2.9	0.2	2.3	2.8
Boise, Idaho	23.0	25.6	24.3	20.8	18.8	16.8	16.8	17.4	16.6	16.1	15.2	11.0	3.8	— 1.2	— 0.4	1.3
Ely, Nev.	23.2	...	24.0	21.8	18.8	16.4	15.4	15.9	16.0	15.7	14.7	12.2	5.2	— 0.5	— 2.4	— 1.2
Phoenix, Ariz.	21.6	22.6	20.9	19.6	18.3	16.3	15.4	15.3	16.0	16.0	15.9	15.4	13.9	7.8	2.1	— 0.6
Billings, Mont.	31.7	...	25.1	23.2	21.0	19.5	19.0	19.0	18.8	17.7	14.9	8.5	0.0	— 4.0	— 3.8	— 2.6
Denver, Colo.	26.3	...	23.1	20.6	19.1	17.5	17.2	17.5	18.6	19.0	16.7	12.2	5.0	— 1.0	— 5.0	— 5.3
Albuquerque, N. Mex.	22.2	...	21.8	19.6	16.5	14.7	14.1	14.9	16.1	16.5	16.0	14.1	6.6	0.2	— 2.6	— 3.4
El Paso, Tex.	24.3	...	20.0	17.1	15.0	13.3	13.6	14.6	15.8	16.5	16.1	14.4	9.1	3.1	0.0	— 1.9
Bismarck, N. Dak.	37.3	34.5	25.9	23.8	23.0	23.1	23.7	23.6	23.2	21.8	17.8	9.6	0.1	— 4.5	— 2.3	...
Omaha, Nebr.	36.9	30.7	23.7	23.4	22.4	22.2	22.0	22.4	22.7	21.8	19.1	12.6	4.7	— 0.6	— 2.0	— 3.1
Oklahoma City, Okla.	27.1	24.8	20.6	19.2	17.7	16.2	15.0	17.5	17.6	18.4	17.7	15.0	8.4	2.1	— 2.3	...
San Antonio, Tex.	20.5	17.6	12.8	12.8	11.0	10.4	11.8	12.8	13.3	13.7	13.3	12.0	8.3	4.6	1.8	— 1.3
Minneapolis, Minn.	33.3	27.1	23.1	21.5	22.4	23.0	23.2	23.5	21.4	18.4	13.6	6.3	— 0.5	— 4.3	— 2.5	— 1.5
Joliet, Ill.	27.1	28.7	24.1	20.5	20.9	21.6	21.6	21.5	20.1	17.3	12.4	5.3	— 1.4	— 5.4	— 6.0	— 3.9
St. Louis, Mo.	31.7	30.4	22.4	23.0	22.8	22.4	22.3	22.7	22.1	20.0	16.3	9.6	1.6	— 1.4	— 3.1	— 3.1
Nashville, Tenn.	25.7	24.9	20.0	17.3	16.6	16.5	17.5	17.6	17.4	15.7	13.6	7.4	— 0.4	— 5.2	— 7.5	— 8.3
Atlanta, Ga.	22.9	20.2	16.5	14.1	13.1	13.3	14.1	15.3	16.0	16.2	13.7	9.2	2.8	— 2.7	— 3.8	— 3.8
Pensacola, Fla.	23.0	17.4	12.7	10.5	9.4	9.5	10.5	11.6	12.3	12.0	11.4	9.0	4.0	— 0.3	— 4.1	...
Sault Ste. Marie, Mich.	23.4	27.1	23.0	19.0	20.3	21.2	21.8	21.9	19.4	15.7	10.3	5.2	0.5	0.4	1.5	...
Buffalo, N. Y.	22.5	24.8	21.8	19.8	19.6	19.7	19.9	18.7	16.6	13.7	9.8	5.5	1.8	0.3	0.5	1.4
Lakehurst, N. J.	25.8	27.5	23.5	21.5	21.4	22.1	22.8	22.7	21.1	18.7	14.4	8.9	2.2	— 2.4	— 5.4	— 6.6
Washington, D. C.	26.7	27.0	22.2	20.5	20.5	21.1	21.6	22.0	21.8	19.4	15.0	7.9	1.4	...	...	...
Charleston, S. C.	21.8	18.7	15.9	13.8	13.0	13.5	14.3	15.3	16.1	15.9	13.8	9.7	3.5	— 1.6	— 3.4	— 2.8
Miami, Fla.	13.1	9.8	7.9	6.4	6.0	5.1	5.9	6.9	7.2	7.2	6.9	5.6	3.7	1.8	0.1	...
ALASKA																
Fairbanks	37.1	25.0	16.9	14.6	15.6	16.3	17.3	16.9	15.9	14.3	10.9	5.6	3.9	6.1	7.8	9.8
Juneau	13.0	11.1	9.1	7.8	7.3	7.7	7.9	7.4	7.2	6.3	4.6	1.7	3.1	5.2	5.5	5.9

9. THE TWO INVERSIONS

For Sault Ste. Marie the lapse rates of temperature per 1,000 m. are recorded in table 5 for the months July 1939 to February 1941. Only the data from 5 km. up have been taken. The isallorhythms show two interruptions in the areas of maximum decrease of temperature of more than 7°, the first for March 1940, the second for

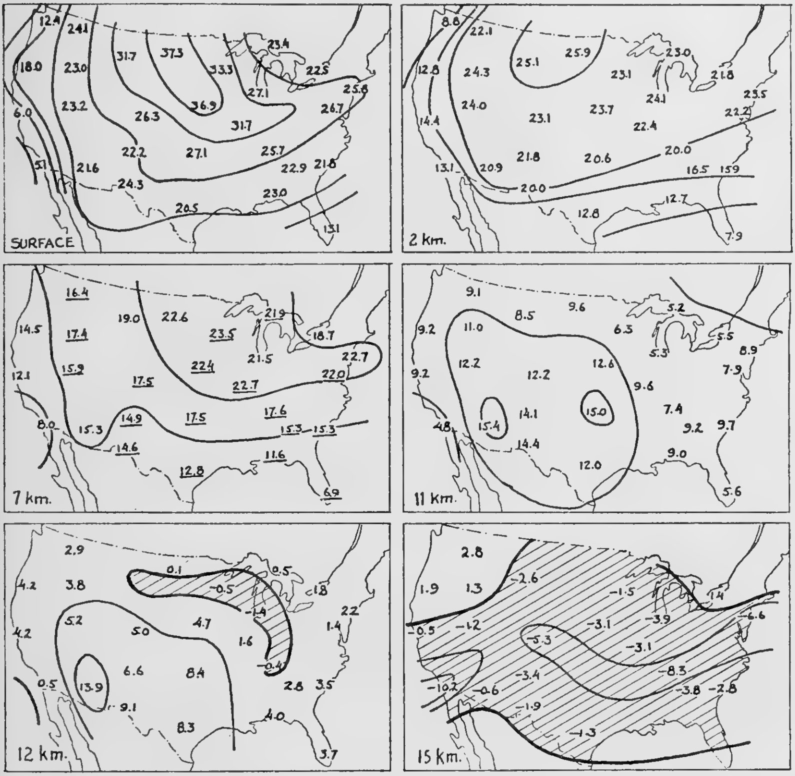

FIG. 13.—Temperature differences, July-January, 1940.

January 1941. The altitudes of the maxima of lapse rates are highest during the summer and lowest during the winter months, respectively 8-9 and 6-7.

The altitude of the first inversion goes from 10 up to 13 km. during the months January to May, 1940. For July to September, 1939, and August and September, 1940, no first inversion can be distinguished, differences in plus being observed only from 16 km. up. A selection of diagrams of lapse rates simplifies comparisons. Figure 14 gives

TABLE 5.—*Lapse rates of temperature, Sault Ste. Marie*

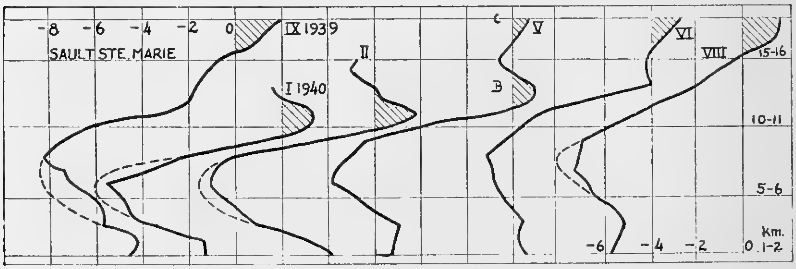

FIG. 14.—Lapse rates of temperature, Sault Ste. Marie.

those for September 1939, January, February, May, June, and August, 1940.

In May there are two perfectly characteristic inversions: one at B with a maximum of +1.0 between 13 and 14 km., the other of +0.7 at C between 18 and 19 km.

The lower inversion has a well-pronounced annual variation of altitude: December to March between 11 and 12; April, 12-13; May, June, July, 13-14 km. In August nothing more than a slight inflexion of the curve of lapse rates remains between 13 and 14 km. On the curve for September 1939 (fig. 14) this inflexion is more accentuated (12-13) and still more (13-14) on the curves for October and November. The beginning of the upper inversion, C, is at 14 km. in December 1939, at 17 in April and May, at 16 June to October, 1940, and also at 16 km. July to October, 1939.

A comparison of the reproduced curves leads to interesting suggestions on tropospheric changes from month to month.

The curve for September is not what it should have been between 4 and 8 km., the lapse rates being nearly 1.°5 C. less than on the regular punctuated curve, with a maximum for 7-8. The curves for May and June are more regular. But in August we see again a reaction in the values of 6-7 to 8-9: a tendency of tropospheric inversion. Finally, the regular decrease of temperature from 1 km. up to 4 km. on the curve for February is in contrast to the curve for August of decreasing lapse rates up to 4 km.

Comparing all available data for February 1940 we find that the lower inversion, properly speaking, does not extend south of Oakland nor south of the 36th parallel.

With the exception of Medford and Oakland, of higher levels, and Spokane, St. Paul, and Sault Ste. Marie, of lower levels, all other stations give 11-12 km. as their characteristic increase of temperature. The lower level of 10-11 km. at Spokane may also be observed farther north in Fairbanks.

South of the 36th parallel the lower inversion, properly speaking, does not exist, although all the curves show an inflexion corresponding to the inversion: between 11 and 12 km. at Albuquerque, Oklahoma City, and Nashville; at 12 in Atlanta and Charleston; between 12 and 13 at San Diego, Phoenix, Pensacola, and very slightly at Miami; while the curve of San Antonio also shows an inflexion between 13 and 14 km. In other words, from the north to the south the influence of the lower inflexion is going higher up.

Now, for the upper tropopause, so distinctly marked on the curve of May for Sault St. Marie (C on fig. 14), the available data suggest an overlapping, from south to north, and its final disappearance in higher latitudes.

The following diagrams (fig. 15) of lapse rates for May 1940 are good examples showing the gradual disappearance of the lower inversion going south, from the Canadian border to the Gulf of Mexico, or, in the southern States, going west-east from Arizona to Florida.

An overlapping of the two tropopauses, with the upper gradually disappearing in the north, is perfectly demonstrated by this diagram.

To sum up: we must make a distinction between two types of stratosphere—the stratosphere of tropical regions, above 19 km. of altitude, and the stratosphere of high latitudes, extending down to 10 or 9 km. in Alaska. They overlap in the United States where a distinction between a lower and an upper stratosphere should be made.

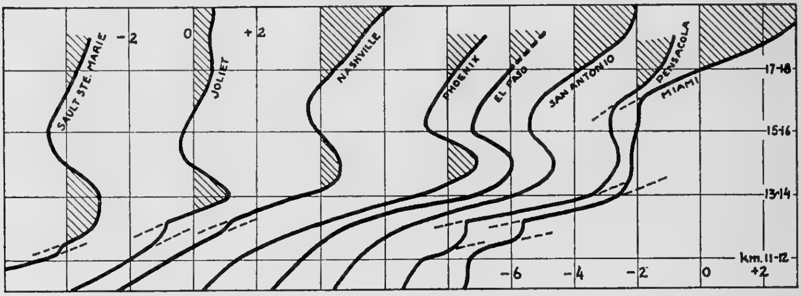

FIG. 15.—Lapse rates for May 1940.

In a study of the annual variations of temperature over Lindenberg a substratosphere (the pseudo-stratosphere of Jaumotte) has been admitted by J. Reger and, before him, by Schmauss [22] but nowhere in Europe do the monthly mean data give such convincing information on the coexistence of an upper and a lower tropopause as do those of the American stations.

Then, for the troposphere, a distinction between high and low altitudes should also be made, best perhaps for the altitudes above and below the levels of the highest lapse rates. Finally, in the lower troposphere the individuality of an active bottom zone, of the most frequent inversions, should perhaps also be recognized. This active troposphere is continental. It does not extend over the Atlantic.

[22] Schmauss, A., Die Substraposphäre. Beitr. Phys. Freien Atmosph., vol. 6, p. 153, 1914.

10. THE SUBSTRATOSPHERE

It is perhaps at Fairbanks, Alaska, that the annual variation of the altitude of the lower tropopause can be observed best. The selection of diagrams reproduced in figure 16 shows that in March the tropo-

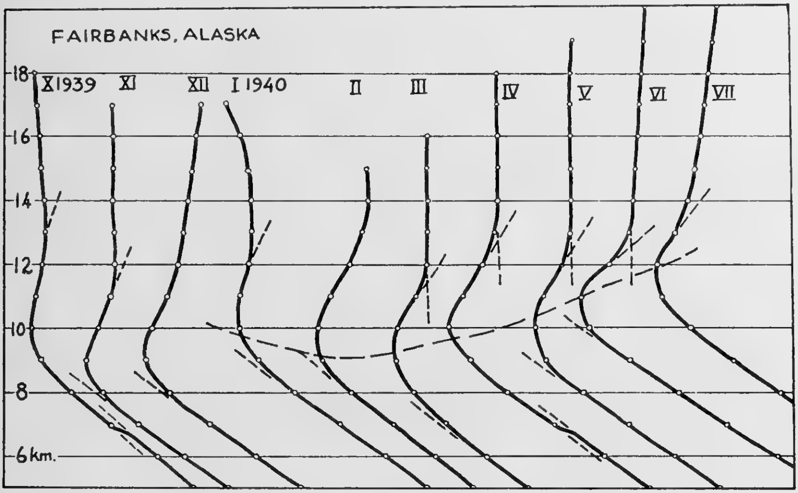

FIG. 16.—The tropopause at Fairbanks, Alaska.

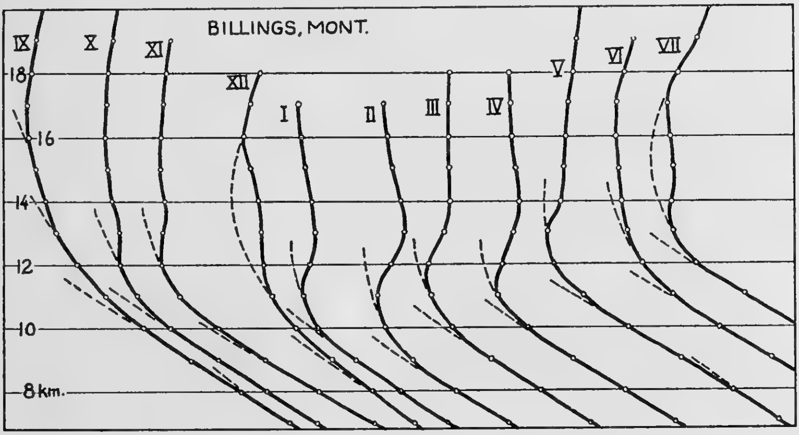

FIG. 17.—The tropopause at Billings, Mont.

sphere extended to an altitude of 9 km. In April and May, 1940, the mean altitudes of the tropopause were observed at 10 km., in June at 11 km., and in July at almost 12 km.—a difference of 3 km. The curve for January shows that as far north as Fairbanks the upper or equatorial tropopause may be observed occasionally during the winter, but lower down, in this particular case at a mean altitude of 16 or 17 km. The selection of curves for Billings, Mont. (fig. 17), shows that in September 1939 there was no lower stratosphere, the mean altitude of the tropopause being between 16 and 17 km. During the months January to July, 1940, there was a gradual increase of altitude of the lower troposphere, from 10 to 13 km., the curve for July shows an increase of temperature at 15 km. and the upper tropopause at 17 km. or slightly above that altitude.

The curves for Lakehurst, N. J. (fig. 18), are particularly interesting. In October 1939 we can see inflexions at 10 km. and between

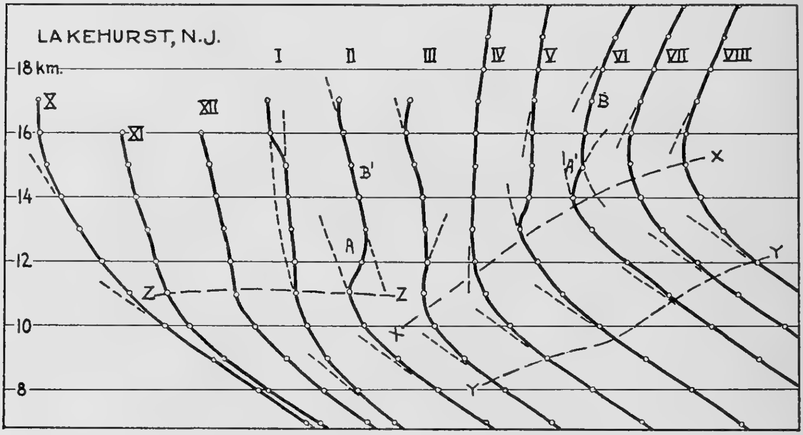

FIG. 18.—The tropopause at Lakehurst, N. J.

13 and 14 km., but no lower tropopause. In January there is a lower tropopause at the altitude of 11 km. In February the lower tropopause is well pronounced, but then an upper tropopause, slightly above 16 km., was also observed at the same altitude as in October.

The mean values for March and April give transitional stages to the curve for June. But in June it is at B between 16 and 18 km. that we observe a portion of the curve corresponding to the general disappearance of the lower tropopause. In July this is not so. Then the step A′ between 14 and 15 km. would correspond to A between 11 and 13 km. of the curve for February and B′ on this curve would then correspond to B of June.

The seasonal effect upon the extent in altitude of the tropopause is well indicated by these curves. From July to October there is analogy to tropical conditions, but with a tropopause at 16 km., about

3 km. lower than under the Equator. In April, on the contrary, perfect analogy exists with Arctic conditions, but with a lower tropopause 2 km. above the altitude observed at Fairbanks.

An overlapping of the two types is also evident, and this means that the upper tropopause is nothing but the base of the tropical stratosphere, in the United States extending to lower altitudes than under the Equator, while the lower tropopause is the regular tropopause of Arctic regions. Therefore, the substratosphere of the months January to April, in particular, is nothing else but a southern extension of the stratosphere of Alaska, with a tropopause growing gradually higher, going south.

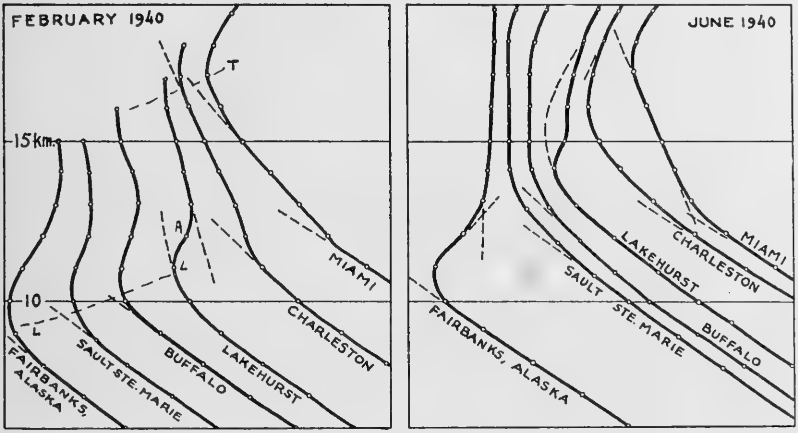

FIG. 19.—The tropopause in February and June, 1940.

The fact of a coexistence of two stratospheres, over the northern States in particular, leads to many questions, which will be answered in due course of time.

What are the effects of the day-to-day changes of the overlapping of the two stratospheres on atmospheric pressure and on the formation of lows and highs at the earth's surface? Evidently, the first question that needs to be answered is the reason for such changes. Are they similar to seasonal changes? And if so, what reasons could there be for the stratospheric and substratospheric changes, or equatorial and Arctic interactions, if the active effect above all the cloud levels of the troposphere was independent of eventual changes of solar-radiation intensity? A direct effect should exist from day to day just as it exists from season to season.

Let us compare the following temperature diagrams of Fairbanks, Sault Ste. Marie, Buffalo, Lakehurst, Charleston, and Miami for the months of February and June, 1940 (fig. 19). In February the tropopause L of Fairbanks is 2 km. higher in Lakehurst. The inversion A of Lakehurst may still be observed in Charleston, while in Miami it is only slightly accentuated. The upper tropopause of Lakehurst corresponds to the tropopause T of Miami. But the overlapping of the upper stratosphere over the substratosphere extends farther north to Sault Ste. Marie and perhaps as far as Alaska. Such is not the case in June. Then, if in Buffalo we still may have an upper tropopause, at an altitude of 17 km., and perhaps also at Sault Ste. Marie, the curve for Fairbanks shows no trace of it.

It is interesting to compare the increase of temperature from 17 to 19 km. of altitude. For June the figures are: Miami 5.7, Charleston 4.2, Lakehurst 3.6, Buffalo 2.6, Sault Ste. Marie 2.2, and Fairbanks 0.8. The upper inversion is therefore, without any doubt, connected with the temperature conditions of the tropical regions, whereas the lower inversion belongs to the Arctic regions.

A comparison of the temperatures at 10 and at 16 km. shows a reversal of the latitude effect. For June we have the following means:

	Altitude	
	10 km.	16 km.
Batavia	—31.9	—81.2
Lake Victoria	—34.1	—70.4
Miami	—35.1 ↓	—71.5 ↑
Charleston	—36.6	—68.6
Lakehurst	—40.0	—60.1
Buffalo	—42.4	—60.1
Sault Ste. Marie	—44.1	—57.5
Fairbanks	—53.9	—46.4

Below the lower inversion, these figures show a decrease of temperature with increase of latitude. Above, on the contrary, the temperatures are increasing with an increase of latitude.

It is interesting to compare maps of temperature for different altitudes. For June and at an altitude of 11 km. the temperatures are lower all over the United States and in Alaska than the mean for Miami: Juneau —7.5, Fairbanks —12.3, Portland, Oreg., —10.7, ... San Antonio —1.8, Pensacola —1.6, and Charleston —2.0 lower than that of Miami. At an altitude of 12 km. the two Alaskan stations have higher temperatures than the —50.9 of Miami, for there we are already above the tropopause. At 14 km., all over the United States temperatures are higher than at Miami.

A regular increase with latitude is characteristic, a reversal of the conditions observed at lower altitudes. At Seattle the mean temperature is 8°3 higher than at Miami and 7°4 at Sault Ste. Marie.

In January the map for an altitude of 13 km. is characterized by positive departures all over the United States, with a maximum of 6°1 in Buffalo, while at 11 km. temperatures were still everywhere below the −49.2 of Miami, as much as 11° lower in Boise and Oklahoma.

11. TROPOSPHERIC LAPSE RATES

The curve of lapse rates per 1,000 m., as they have been observed in Omaha in March 1940, shows that a distinction must be made

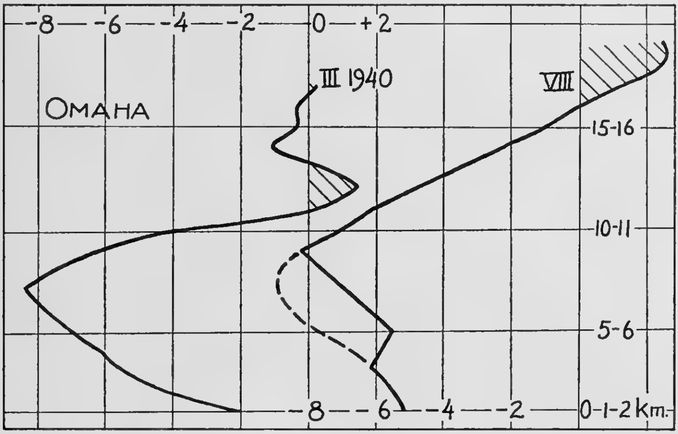

FIG. 20.—Lapse rates, Omaha, Nebr.

between a lower troposphere of increasing lapse rates and an upper troposphere characterized by decreasing values with altitude.

The conditions in August differ essentially from those of March (fig. 20). Then, when the tropopause is higher, the lower troposphere shows a distinct tendency, between 3 and 6 km., to counteract an exaggerated increase of the lapse rates. Temperatures up to an altitude of 8 or 9 km. do not decrease as much as they would if the conditions were the same as in March.

Taking the differences of lapse rates between 3 to 4 and 5 to 6 km., we find a decrease south and west and an increase north and east of Omaha. The figures are shown in table 6.

The highest lapse rates, or let us say the altitude extent of the lower troposphere, is 7°3 from 7 to 8 km. at Sault Ste. Marie; at Pensacola the figure is 8°6 for 11 to 12 km. In other words the lower troposphere reaches an altitude 4 km. higher in Florida than on the Great Lakes.

The data for March are given in table 7.

Negative differences appear only for Denver, Albuquerque, and El Paso. The altitudes of maxima lapse rates are lowest at Sault Ste. Marie and Joliet: 5-6 km. The highest, 9-10 km., are observed in San Diego and Miami. But the increase of altitude is not regular going from north to south. From the Great Lakes to southern California the figures are: 5-6, 6-7, 7-8, 6-8, 7-8, 9-10. An axis of higher altitudes extends from Bismarck to Charleston, and one of lower altitudes, from Medford to Atlanta.

TABLE 6.—*Lapse rates for August 1940*

	Altitude, km.		
	3-4	5-6	Differences
Bismarck, N. Dak.	6.1	6.6	0.5
Charleston, S. C.	4.9	5.6	0.7
Denver, Colo.	7.2	7.0	— 0.2
El Paso, Tex.	7.3	6.0	— 1.3
Ely, Nev.	8.8	8.2	— 0.6
Joliet, Ill.	5.6	6.0	0.4
Lakehurst, N. J.	4.9	6.0	1.1
Medford, Oreg.	6.8	6.5	— 0.3
Nashville, Tenn.	5.3	5.1	— 0.2
Oakland, Calif.	6.6	7.0	0.4
Oklahoma City, Okla.	6.5	5.9	— 0.6
Omaha, Nebr.	6.2	5.4	— 0.8
Pensacola, Fla.	6.0	5.8	— 0.2
Phoenix, Ariz.	7.3	4.8	— 1.5
San Diego, Calif.	7.6	6.3	— 1.3
Sault Ste. Marie, Mich.	5.1	6.4	1.3
Seattle, Wash.	5.1	6.5	1.4
Washington, D. C.	5.1	6.0	0.9

It would be interesting to compare these figures with the mean altitudes of cloud levels, of the lowest levels of *Ci* clouds and the highest of *Al-Cu* clouds in particular.

The monthly means are evidently affected by the frequent inversions occurring in the lower troposphere. The temperature curves, up to 6 km. in altitude, for Omaha for the months January and May are reproduced on figure 21. Below 3,500 m., in January, temperatures are much lower than they would be if the lapse rates of increase from 6 to 4 km. persisted.

The differences of the mean temperatures between the earth's surface and an altitude of 6 km. may serve for comparisons on the importance of the lower inversions. For January 1940 the difference is 15°.9, while in June the increase of temperature is 31°.7—nearly double. The annual variation, reproduced in figure 22, is regular, at least very much more so than for other stations.

The differences, mean temperature at 6 km. and at surface, show that in January the maximum effect of the lower inversions coincided with the axis of continentality. The differences are: Bismarck 15.4, Omaha 15.9, Oklahoma City 18.7, Pensacola 20.9. East and west

TABLE 7.—*Lapse rates for March 1940*

	Altitude, km.								
	3-4	5-6	Difference	6-7	7-8	8-9	9-10	10-11	11-12
Albuquerque, N. Mex.	7.9	7.0	— 0.9	7.8	7.7	7.7	7.0	6.6	...
Atlanta, Ga.	5.4	7.1	1.7	7.8	7.8	7.8	7.2	6.1	...
Billings, Mont.	6.9	7.2	0.3	7.8	7.8	7.5	6.0	3.3	...
Bismarck, N. Dak.	5.2	7.0	1.8	7.8	8.2	8.1	6.1	...	...
Boise, Idaho	6.0	6.6	0.6	7.9	7.8	7.7	6.8	5.1	...
Buffalo, N. Y.	5.2	6.6	1.4	7.5	6.8	5.8	...	...	...
Charleston, S. C.	5.6	6.9	1.3	7.4	8.1	7.6	7.7	6.1	...
Denver, Colo.	7.2	7.0	— 0.2	8.9	8.0	7.8	7.2	5.0	...
El Paso, Tex.	7.0	6.9	— 0.1	7.9	8.0	7.5	7.5	...	...
Ely, Nev.	6.4	7.3	0.9	7.8	7.8	7.4	7.3	...	...
Joliet, Ill.	4.7	7.2	2.5	7.0	6.9	6.7	6.0	...	...
Lakehurst, N. J.	5.0	7.0	2.0	7.4	7.1	6.6	4.3	...	...
Medford, Oreg.	6.3	6.8	0.5	8.5	8.0	7.3	...	...	...
Miami, Fla.	5.9	6.3	0.4	7.2	7.5	7.5	7.7	7.0	5.4
Minneapolis, Minn.	4.3	6.7	2.4	7.5	7.1	6.3	4.3	...	...
Nashville, Tenn.	6.5	6.8	0.3	7.5	7.7	7.7	6.4	...	...
Oakland, Calif.	6.2	6.8	0.6	7.5	8.1	8.1	7.9	6.9	...
Oklahoma City, Okla.	7.1	7.5	0.4	7.6	7.9	7.3	7.1	...	...
Omaha, Nebr.	5.4	7.0	1.6	7.8	8.3	7.6	6.0	...	...
Pensacola, Fla.	6.2	6.8	0.6	7.5	7.6	7.6	7.5	6.1	...
Phoenix, Ariz.	6.1	7.0	0.9	7.8	7.9	7.7	7.4	...	...
St. Louis, Mo.	5.2	7.2	2.0	7.6	7.8	7.4	6.3	...	...
San Antonio, Tex.	6.4	7.4	1.0	7.6	7.7	7.7	7.5	6.4	...
San Diego, Calif.	6.2	7.1	0.9	7.3	7.7	7.8	7.9	7.7	4.7
Sault Ste. Marie, Mich.	5.2	6.8	1.6	6.4	5.7	4.5	...	...	...
Seattle, Wash.	6.1	6.6	0.5	7.4	7.4	6.7	4.6	...	...
Shreveport, La.	6.4	6.9	0.5	7.2	6.5	...	4.6	...	...
Spokane, Wash.	5.8	6.7	0.9	7.8	7.7	7.5	5.8	...	...
Washington, D. C.	5.3	7.0	1.7	7.3	7.4	7.0	5.7	...	...

the figures increase regularly. The greatest differences are: Medford 29.6, Oakland 31.2, San Diego 31.7, and, on the Atlantic side: Sault Ste. Marie 27.9, Buffalo 29.0, Lakehurst 25.7, Miami 25.8. The extreme values of 31.7 and 15.4, for San Diego and Bismarck differ by 16.3.

In June the axis of lower figures extends across the continent from the Pacific to the Atlantic. We have: Oakland 24.2, Ely 25.0, Denver 26.9, Bismarck 27.7, Sault Ste. Marie 27.7, Joliet 28.7, Lakehurst 27.5, and above 30° in Medford, Boise, Billings, Spokane, and Seattle, as well as in the southern and midwestern States. The highest figures are: Phoenix 37.2, El Paso 32.7, San Antonio 31.4, Pensacola

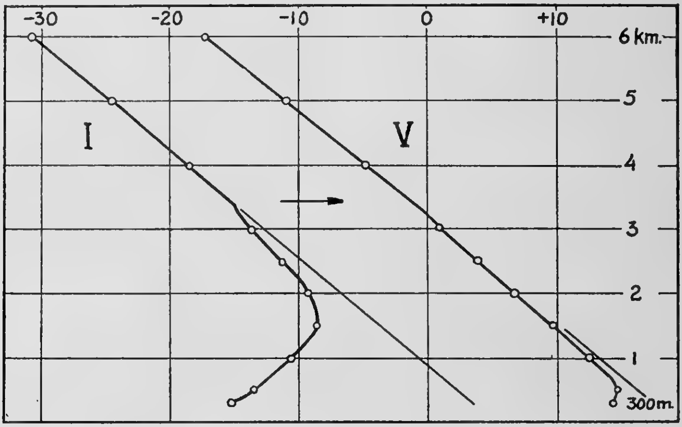

FIG. 21.—Temperature curves up to 6 km. in altitude for Omaha, Nebr., January and May.

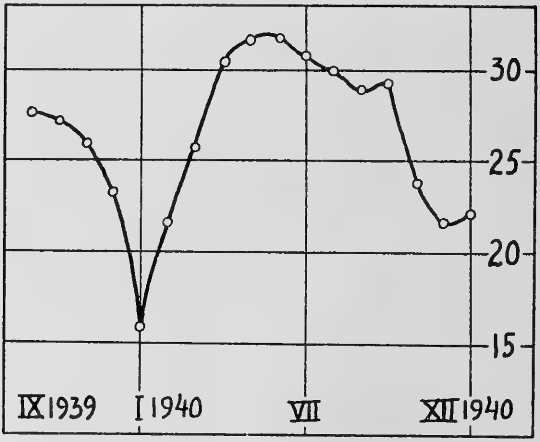

FIG. 22.—Temperature differences, 6 km. and surface, Omaha, Nebr.

33.5, and Miami 31.8. The difference between the highest and lowest figure is 13.0, not very much less than for January.

This radical change from summer to winter may be due directly or indirectly to pressure, maximum on the continent in winter, east and west of the continent during the summer months. But the distribution of the mean pressure is already at an altitude of 3,000 or 4,000 m., very different from what it is at the earth's surface. The first 3,000 m. above sea level should be distinguished from the lower troposphere properly speaking by calling it the active troposphere, or, making use of the Greek word "practicos," call it the "practicosphere" or better still the "practosphere."

We have, therefore, the following sequence: upper stratosphere above the tropical inversion, lower stratosphere above the lower inversion; superposition of both in middle latitudes; then, upper troposphere above the level of the lowest *Ci* clouds, lower troposphere of increasing lapse rates, and finally, down below, the practosphere.

It may be that in any studies on the possible effects of solar-constant variations these five units of the meteorologically accessible atmosphere should be examined separately.

12. ATMOSPHERIC CIRCULATION

In any study on the general atmospheric circulation a distinction should be made between the Northern and Southern Hemispheres and between summer and winter.

During the winter of the Southern Hemisphere we have a center or centers of extreme cold and high pressure on the Antarctic continent with a low-pressure belt all around it, along the 60th parallel, let us say. The high-pressure centers of the South Atlantic, the Indian Ocean, and the South Pacific are united over the continents and form a belt between the equatorial low-pressure areas and the ring of low pressures surrounding Antarctica.

During the winter months of the Northern Hemisphere there are, on the contrary, two distinct centers of cold and, in consequence, the high-pressure areas of Asia and North America. Between these continental anticyclonic centers, we have a more or less continuous tendency to the formation of a belt of low pressure uniting, across the Pole, the centers of action of low pressure of the North Atlantic and the North Pacific.

During the summer months conditions are evidently very different, over the Northern Hemisphere at least. The transport of air masses in the course of a year, from one hemisphere to the other or from continent to ocean, can be studied best by comparing world maps of monthly departures from annual means. Such maps have been discussed by the author.[23]

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[23] Arctowski, Henryk, Nouvelles recherches sur la marche annuelle de la pression atmosphérique. Inst. Geof. i. Meteorol., Uniw. Lwów, Kom., vol. 4, No. 50, pp. 354-397, 1929.

Annual pressure variations for individual stations have also been studied extensively,[24] as well as the maps of the differences from month to month of normal means and of those for individual years.[25]

For the years 1910-1919 in particular, making use of the monthly means of the Réseau Mondial, Teśla traced the maps of departures, from annual normals, of overlapping 12-monthly means and monthly departure maps for the individual years.[26]

All these researches should have been an introduction to a study of world weather changes from day to day, a study on the formation, the displacements, and the intercrossings of baroterons or pressure waves, as observed on the earth's surface. A very respectable number of such maps, prepared by private assistants and students of the author at the Geophysical Institute of Lwów University, may be considered lost or not available because of the war.

However, a preliminary research of Moniak and the author,[27] for the months of February, March, and April, 1911, shows plainly that it is only by studying the pressure changes occurring all over the world that it may be possible to explain the direction and rate of displacement of a teron, observed on a given day, in the United States for example.

In this research, maps of daily departures from monthly means have been compared in order to fix the displacements of areas of positive and negative departures.

The following citation from the French summary of this paper may be useful:

La comparaison des cartes synoptiques des États-Unis, avec celles de l'Argentine, ainsi que des cartes de l'Australie et de la Chine, nous a permis de constater des coïncidences, dans les désplacements des centres de basse ou de haute pression, qui nous forcent de présumer que, parfois, il y a une certaine corrélation dans la marche du temps au *N* et au *S* de l'équateur. Les cartes synoptiques de l'Inde, de l'Égypte et de l'Europe, comparées entre elles, jour par jour, révèlent aussi de fréquentes dépendances mutuelles dans les changements du temps. Il est aisé de représenter cartographiquement les déplacements de masses atmosphériques

[24] Arctowski, Henryk, Sur les discontinuités dans la marche annuelle de la pression atmosphérique. Ibid., vol. 3, No. 42, pp. 601-616, 1928.

[25] Arctowski, Henryk, Remarques au sujet des variations des marches annuelles de la pression. Ibid., vol. 7, No. 83, pp. 162-173, 1934.

[26] Teśla, J., Les baropleions des années 1910 à 1919. Ibid., vol. 9, No. 118, pp. 216-376, 1937; Sur les anomalies mensuelles de la distribution de la pression atmosphérique, d'après les données du Réseau Mondial. Ibid., vol. 10, No. 131, pp. 144-209, 1939.

[27] Arctowski, Henryk, and Moniak, Jan, Sur les changements d'un jour à l'autre dans la distribution de la pression atmosphérique. Ibid., vol. 4, No. 47, pp. 188-210, 1929.

qui surviennent, en prenant les différences des valeurs journalières par rapport à la moyenne du mois. Ces différences des pressions observées à 8^hp. ex., par rapport à la moyenne du mois, correspondent parfaitement aux variations d'un jour à l'autre. . . . . .

La comparaison des cartes faites dans le but de noter les déplacements des positifs et des négatifs, nous permet d'affirmer qu'il n'y a pas de prédominance de mouvements de l'*W* vers l'*E* tels qu'un négatif puisse contourner le pole. Les routes des déplacements sont compliquées et ne semblent pas être coordonnées suivant un plan déterminé. Fréquemment, les changements dans la distribution des positifs et des négatifs surviennent subitement en quelque sorte et cela au point que, dans ces cas, il devient difficile de décider si nous avons à faire à un déplacement rapide ou à un mouvement en bascule. Les cartes donnent l'impression d'un certain rythme tout comme si l'atmosphère terrestre, dans son ensemble, subissait des influences perturbatrices à des intervals d'un certain nombre de jours.

Farther on it has been specified that such purturbating influences might probably be ascribed to variations of the intensity of solar radiation. If such is really the case, it would follow that all the day-to-day anomalies, in the distribution of atmospheric pressure, are simply the indirect effects of solar-constant changes. How and why, is the question to be answered.

No attempt at giving a correct answer to this question could be made without making use of upper-air data. One example will be sufficient to justify this statement. Nowhere is the annual variation of temperature (and consequently of pressure as well) expressed by a continuous rise and fall. On all curves discontinuities are the rule. In central Asia the July temperatures are not as high nor the pressures as low as they should be if counteracting oceanic effects were not the cause of characteristic breaks in the annual variation curves. Also in January the temperature is higher and the pressure lower than they should be under a full and exclusive effect of continentality.

The reproduction of a map (figure 23) expressing a comparison of the mean pressures for September and October is justified.[23] The small circles O signify that for the given station the curve of the annual variation is continuous between these 2 months. The signs + and − serve to indicate an up in the case of descent to the winter minimum (as in Iceland for example), or a down in case of ascent (in Asia and North America). Finally the signs ◡ and ◠ stand for minima or maxima without discontinuity. We notice, in central Asia, how the stations of discontinuity of rise of pressure are coordinated and alternate with spaces of no discontinuity. The countereffect of the Icelandic minimum tendency acts by steps upon the rising high

[23] Arctowski, Henryk, Nouvelles recherches sur la marche annuelle de la pression atmosphérique. Ibid., vol. 4, No. 50, p. 387, 1929.

pressure of the Asiatic winter. Similar to the seasonal effect must be the effect of abnormally increasing or decreasing solar-constant values.

Then, just as in the case of seasonal variations, a decrease of solar radiation will have a maximum effect there where the possibility of change of temperature is greatest: at the centers of continentality. But, taking into account the complexity of the atmosphere, the absence or the existence of extensive cloud levels at different altitudes, we have to admit that the maximum effect of the impulse of a solar-constant change should be observed not only at the centers of continentality, probably there at the bottom of the atmosphere, in the practosphere, but also in the lower troposphere, irrespective of continentality, over the levels of water-drop clouds[29] which prevent a

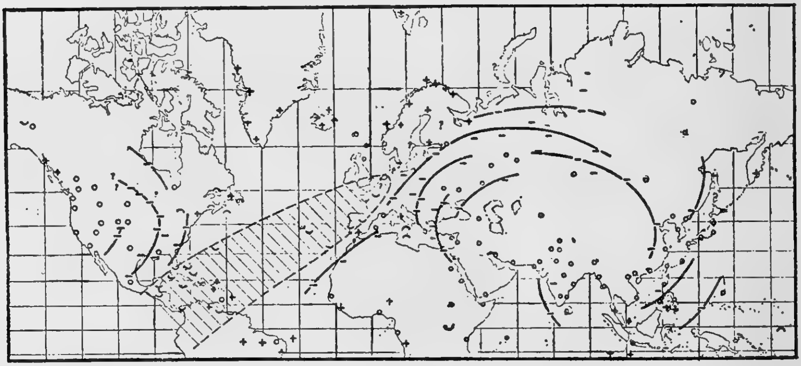

FIG. 23.—Pressure differences for September and October.

direct effect of the solar impulse upon the practosphere, or even higher up, in the upper troposphere or over the horizons of the ice-crystal clouds, in the lower stratosphere.

The resulting changes of pressure and air currents at the earth's surface should therefore be regionally different under the impulse of any solar change of intensity of radiation.

Let us now suppose the existence of a cloudy atmosphere all over the world. Then the effect of continentality would be subtracted from the problem and the direct impulse of a solar-constant change would

[29] To measure the reflecting power of level cloud surfaces, L. B. Aldrich made use of a pyranometer suspended below the basket of an Army observation balloon. More than 100 determinations were made. A mean value of 78 percent was obtained. Using 78 percent as the cloud reflecting power the albedo of the earth (as defined by Bond) becomes 43 percent. Ann. Astrophys. Obs. Smithsonian Inst., vol. 4, p. 380, 1922.

be felt in the stratosphere, especially over the equatorial regions. There, an increase of the solar constant would bring the tropical tropopause lower down, let us say to an altitude of 16 km. instead of 18 or 19 km. This would directly affect the middle latitudes. Besides, supposing rhythmical changes in plus and minus of the solar action, waves of altitude increase and decrease would advance from the Equator toward high latitudes. Admitting a very distinct difference between a western and an eastern hemisphere—as for example the hemisphere of the Pacific Ocean and the hemisphere of maximum of continentality—changes of the solar constant would produce a see-saw effect or, more probably, atmospheric waves extending from Pole to Pole and moving eastward, rotating faster than the earth.

Such speculations may be considered a working hypothesis, a justification of questions to be answered.

13. THE DIRECT HIT

Generalizations may simplify a problem to be solved. In our case it is not so, because not only at the earth's surface the regions of a direct response to a maximum or a minimum of solar radiation should differ with a change of atmospheric conditions, but also such changes must produce regional effects upon the upper atmosphere and the direct hit may be high up or lower down, according to circumstances.

Let us pass to a practical example of eventual effects of a solar-constant variation upon the temperatures observed at a given altitude. The solar-constant values, as they have been observed during the days of October 17-24, 1939, at the Smithsonian South American station, are:

October 17	18	19	20	21	22	23	24
1.930	*41*	32	28	*37*	*37*	32	34

Maxima occur on the 18th and 21st-22d, minima on the 20th and 23d. The temperatures observed at Boise on these days at an altitude of 12 km. were:

October 17	18	19	20	21	22	23	24
—64.1	*—55.6*	—62.0	—61.6	—58.0	*—57.3*	—60.9	—57.7

These figures show practically identical variations: higher solar-constant value, higher temperature at 12 km.

But higher and lower than the altitude of 12 km. the variations of temperature differ; they no longer correspond to the variation of the solar constant.

The figures of the following table giving temperature differences from day to day at altitudes from 3 to 17 km. show that at 11 and 13 km. we observe variations similar to that of 12 km., whereas going down, a tendency toward a retarded variation may be assumed.

The temperature soundings are made during the night, shortly after midnight Washington time, and the solar-constant data are morning observations of the same date. The difference of longitude of about 10° does not matter, but the time difference, Montezuma observations being made 6 or 7 hours later than the soundings, shows that if there is, besides the time difference, a slightly retarded effect between cause and effect, it should be at dates following those of the Montezuma

TABLE 8.—*Temperature differences from day to day: Boise, Idaho, altitude 824 m.*

	October							
Altitude	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24
Surface....	+ 1.2	− 3.5	− 3.5	+ 0.3	+ 0.4	− 0.3	− 0.5	+ 6.9
3 km......	+ 0.6	− 6.3	+ 2.8	− 0.5	+ 4.9	+ 2.9	− 2.9	− 3.5
4 km......	+ 2.9	− 7.1	+ 3.7	+ 2.7	+ 5.1	− 2.0	− 0.8	− 5.9
5 km......	+ 0.3	− 2.2	− 1.1	+ 7.0	+ 3.0	− 4.3	+ 0.5	− 4.7
6 km......	− 3.0	− 0.6	+ 1.5	+ 3.3	+ 3.6	− 3.7	− 0.3	− 5.4
7 km......	− 4.7	+ 0.1	− 0.4	+ 6.5	+ 2.9	− 4.3	− 1.3	− 3.9
8 km......	− 2.5	+ 1.5	− 3.7	+ 6.0	+ 4.2	− 4.5	− 1.3	− 1.7
9 km......	− 2.6	+ 0.8	− 4.5	+ 5.9	+ 6.1	− 4.7	− 2.3	− 2.8
10 km......	− 3.4	+ 1.2	− 5.3	+ 5.7	+ 5.7	− 2.6	− 3.8	− 1.3
11 km......	− 3.2	+ 5.0	− 8.8	+ 6.1	+ 4.9	− 1.7	− 3.1	− 1.2
12 km......	− 2.3	+ 8.5	− 6.4	+ 0.4	+ 3.6	+ 0.7	− 3.6	+ 3.2
13 km......	− 0.1	+ 7.0	− 2.3	− 0.5	+ 0.7	− 0.4	− 0.6	+ 0.6
14 km......	+ 1.3	+ 3.1	+ 1.6	− 1.0	− 1.6	− 0.9	+ 0.9	+ 1.9
15 km......	+ 1.8	− 2.2	+ 2.4	− 1.1	− 2.8	− 0.6	+ 1.0	+ 3.5
16 km......	+ 2.1	− 6.4	+ 6.4	− 4.9	− 3.6	− 0.1	+ 2.9	+ 7.8
17 km......	+ 1.6	− 5.5	+ 5.9	− 5.9	− 3.3	0	+ 3.8	+ 6.2

observations that the effect of the solar-constant anomalies, in plus or in minus, should be observed in the American upper-air data.

Let us compare the curves of the temperatures observed more or less simultaneously, at an altitude of 12 km., all over the United States.

On October 18 the maximum of Boise has also been observed at Spokane, Billings, Medford, Oakland, and Albuquerque. But at Albuquerque and Phoenix the maximum was not well pronounced, and at El Paso and San Antonio no corresponding maximum can be distinguished.

On the curves of Bismarck, Denver, Omaha, St. Paul, St. Louis, Oklahoma City, and Atlanta a characteristic maximum may be observed on the 19th. In Buffalo it appears on the 20th, as it should if we take into consideration the time differences and a possible slight retardation.

For the solar-constant minimum of the 20th, the temperature diagrams show very well-pronounced minima at St. Paul and Nashville and in Oakland, Ely, Denver, Oklahoma City, and Phoenix, whereas north of this west-east belt the minimum occurs on the 19th at Medford and Spokane. At San Antonio the minimum occurs on the 21st. Therefore a north-south displacement is characteristic for the minimum.

The maximum of October 21 or 22 is to be seen on the temperature curves of Billings, Spokane, and Oakland on the 21st, and on the 22d it is well pronounced on the curves of Minneapolis, Sault Ste. Marie, and Buffalo, but not so well on those of Denver, St. Louis, Atlanta, San Antonio, and Miami.

The lack of simultaneity is perhaps less interesting than the difference of the direction of displacement: from west to east for the dates of solar-constant maximum, from north to south for the minimum.

This fact leads to the question whether the direct hit is always observed at an altitude of approximately 12 km. or higher or lower according to season and the annual variation of altitude of the lower tropopause.

14. THERMO-ISOHYPSES

Table 9 gives the interpolated altitudes at which the temperature of $-50°$ has been observed during the second half of October 1939.

The map of the differences of highest and lowest altitudes shows a maximum of 5 km. at Sault Ste. Marie and a difference of 4 km. at Minneapolis. Excluding Lakehurst and Washington, because of insufficient data, differences of less than 2 km. are those of Bismarck, Spokane, Boise, Ely, Oakland, Albuquerque, El Paso, and San Antonio. With the exception of Nashville, all other stations give differences between 2.02 and 2.76 km.

In tracing maps of isohypses one sees that it is only exceptionally that the altitude of $-50°$ does not decrease with increasing latitude. For example on the 27th a north-south axis of highest altitudes extends from Sault Ste. Marie (12.85) across St. Louis (12.15) to Miami (12.20). On the 28th a maximum of 14.10 km. also extends south to the 12.14 of San Antonio and Miami. The same on the 30th: Minneapolis 13.37, Omaha 11.70, Oklahoma City 12.36, San Antonio 11.53. On the 21st a northeast-southwest axis of lowest altitudes extended from Sault Ste. Marie (9.02) to El Paso (10.33).

TABLE 9.—*Altitudes of — 50 °C.*

	October 1939															
	16 km.	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Medford, Oreg.	10.53	10.94	10.50	10.38	10.98	10.90	10.76	10.78	10.40	12.00	9.98	10.17	11.40	10.30	10.50	11.14
Oakland, Calif.	10.74	10.24	11.09	10.30	10.32	11.21	10.60	10.93	10.17	11.60	10.02	10.42	11.58	10.70	10.98	11.60
Spokane, Wash.	9.68	10.38	9.96	9.73	10.26	10.60	10.35	10.54	10.10	8.80	9.16	9.80	10.30	10.40	10.53	9.80
Boise, Idaho	10.36	9.93	10.20	9.44	10.14	10.86	10.61	10.05	9.86	11.00	....	10.46	11.31	9.98	10.25	10.21
Ely, Nev.	10.63	10.71	10.51	10.20	10.35	10.51	10.48	10.67	10.12	....	11.97	(9.96)	....	10.53	10.63	10.64
Phoenix, Ariz.	10.74	10.85	10.56	10.75	10.23	10.70	10.61	10.78	11.00	12.52	....	12.58	11.80	11.38	11.18	11.18
Billings, Mont.	9.75	10.38	(9.92)	9.48	9.87	10.80	10.21	....	9.88	10.10	9.90	11.90	10.15	11.80	10.24	10.10
Denver, Colo.	10.54	10.26	10.70	10.00	9.95	10.66	11.15	10.64	....	11.15	11.97	11.09	11.68	....	10.53	10.26
Albuquerque, N. Mex.	10.55	10.45	10.68	10.73	10.30	10.47	10.71	10.89	11.09	11.10	11.57	....	12.00	10.95	10.47	10.83
El Paso, Tex.	10.72	10.83	10.40	10.52	10.68	10.33	10.97	11.17	11.65	12.02	12.08	11.88	11.83	11.56	11.10	11.14
Bismarck, N. Dak.	9.78	9.75	9.73	9.27	9.35	....	10.17	10.38	....	9.91	9.45	8.89	....	8.97	....	10.12
Omaha, Nebr.	10.43	9.96	10.46	9.96	9.78	9.72	....	10.42	10.10	11.54	11.60	11.66	12.48	9.80	11.70	10.46
Oklahoma City, Okla.	10.35	10.42	10.58	11.57	10.81	....	10.87	10.97	11.17	12.50	11.86	11.85	11.64	11.97	12.36	....
San Antonio, Tex.	11.36	11.26	11.20	11.38	12.24	11.71	....	11.85	12.98	12.82	12.33	11.86	12.14	11.47	11.53	11.46
Minneapolis, Minn.	10.04	9.27	9.90	9.67	9.75	....	12.64	10.24	10.27	9.98	11.50	....	....	9.70	13.37	9.77
Joliet, Ill.	10.06	10.07	10.43	10.19	....	9.94	11.74	9.82	10.30	....	11.47	....	....	10.97	12.00	9.51
St. Louis, Mo.	9.97	9.83	....	10.58	10.30	9.64	10.02	10.10	10.20	10.90	11.79	12.15	12.15	11.27	11.82	11.50
Nashville, Tenn.	9.97	9.90	10.07	11.24	10.21	10.82	10.52	10.43	10.69	....	....	11.96	....	11.90	11.15	12.96
Atlanta, Ga.	11.20	....	11.34	11.57	11.04	11.00	11.40	....	10.64	10.85	11.77	11.89	....	11.80	11.33	11.74
Sault Ste. Marie, Mich.	....	8.95	9.72	9.68	9.25	9.02	13.85	9.00	9.37	9.76	10.04	12.85	14.10	8.70	12.60	9 20
Buffalo, N. Y.	9.77	....	9.67	....	8.89	9.84	9.10	10.12	9.35	9.57	11.50	10.87	....	10.78	9.50	10.67
Lakehurst, N. J.	10.00	....	9.80	10.60	10.56	9.68	9.97	....	9.75	9.86	10.42	....	....	11.29	....	....
Washington, D. C.	....	10.47	10.43	....	....	....	....	....	10.20	10.55	11.58	....	11.63	11.79	....	....
Charleston, S. C.	10.75	11.16	11.05	11.53	....	11.60	10.82	9.37	10.80	11.03	....	12.40	12.25	12.20	11.50	....
Miami, Fla.	11.98	11.88	11.97	....	11.94	11.92	12.70	11.72	12.04	11.56	11.65	12.20	12.14	13.65	11.97	13.07

The maps of differences of altitude from day to day are more interesting. A north-south axis of negatives appears on the 26th-27th from Bismarck to El Paso, on the 27th-28th from Billings to Phoenix, on the 29th-30th from Billings to El Paso, on the 30th-31st from Sault Ste. Marie to San Antonio.

Axis of positive differences: on the 18th-19th from Lakehurst to Phoenix, on the 21st-22d from Sault Ste. Marie to San Antonio, on the 22d-23d from Lakehurst or Buffalo to El Paso, on the 23d-24th from Charleston to San Antonio, on the 25th-27th from Sault Ste. Marie to Miami, on the 29th-30th from Minneapolis or Sault Ste. Marie to San Antonio.

The map of differences between the 18th and the 20th (maximum to minimum of solar radiation intensity) is of particular interest as showing a possible relationship with the solar-constant changes.

It shows an axis of positive values extending from Lakehurst (+0.76) to San Antonio (+1.04). Then, north of it, an axis of negative differences: Buffalo −0.78, Omaha −0.68, Denver −0.75, Oakland −0.77; north of that again positive values for Spokane and Medford.

There is a similar distribution of differences of altitudes between the figures of the 20th and 22d (min.-max. of radiation): positives south-east, Atlanta +1.19, Miami +0.76; negatives, Lakehurst and St. Louis. Then occurs an axis of positive differences extending from Sault Ste. Marie (+4.50) across Minneapolis (+2.89) and Denver (+1.20) to Phoenix (+0.38), and again a negative difference at Medford.

For the 22d-23d differences, there is a similar distribution of figures: negatives south-east, positive values of increase of altitude from Buffalo and Lakehurst to El Paso and Phoenix, negatives again extending from Sault Ste. Marie (−4.85) to Boise (−0.56) and, finally, to the north of this belt, +0.21 at Bismarck and +0.19 at Spokane.

These facts seem to show that the effect of the solar-constant variations upon the altitudes at which temperatures of −50° are reached (beneath the lower tropopause) is registered in forms of waves of higher and lower altitudes.

The day-to-day data of temperatures show, therefore, a similar effect of action and reaction to that observed for the differences of pressure, from month to month, due to the annual variation of temperature, on the earth's surface over Asia (fig. 23).

Intercrossing of waves of temperature increase and decrease are also shown on the maps of differences for the dates 23d-24th, 24th-25th and 28th-29th.

It seems that the problem to be solved now is to find out whether these changes in the altitude-extent of the troposphere, of temperatures above $-50°$, are dictated from below or from above.

15. THE THERMOTERONS OF OCTOBER 17-27, 1939

The temperature changes from day to day are never similar all over the United States. As already remarked, the maps of isallotherms show elongated areas of increase and decrease of temperature. These thermoterons, or anoterons of positive temperature changes and katoterons of temperature decrease, display intercrossings of progressing waves on the maps.

The attempt to trace similar maps of thermoterons for different altitudes showed that the available American upper-air data are just sufficient to search for the relationships that may exist between upper stratospheric or tropospheric altoterons, and the thermoterons observed at the earth's surface. Taking all the temperature changes in 24 hours, tabulated on the U. S. Weather Maps, maps of isallotherms were drawn and at least those of October 17 to 27, 1939, should be described.[30]

But let us now restrict the discussion to those of October 20 and 21 reproduced below (figs. 24, 25).

The map of the 20th, corresponding to a minimum of the intensity of solar radiation, does not show a marked predominance of the extent of katoteron areas, but at the centers of the terons the negative differences exceed the positive. For instance: Grand Rapids, Mich., $-31°$ F., Concord, N. H., $+21$, Fargo, N. Dak., $+24$. In the West: Havre, Mont., $-19°$, Helena, Mont., $+8$, Flagstaff, Ariz., -13, Redding, Calif., and Abilene, Tex., $+10$.

Therefore, taking the entire area of the United States as well as the values of differences, a decrease of the mean temperature is most probable.

The map of October 21, corresponding to an increase of the solar constant, on the contrary, shows an unmistakable increase of temperature; at the centers: $+23°$ F. in Buffalo, against -18 for Concord; in the western States: $+22$ at Havre, -10 at Portland and Modena.

A comparison with the weather maps of the 20th and 21st leads to many questions that cannot be satisfactorily answered.

On the 20th an axis of a high extends from Lake Erie to the Gulf of Mexico, an axis of low pressures extends from Winnepeg to Sioux City and Amarillo, Tex., and, in the western States, isobars show a

[30] They will be studied in detail in another publication.

north-west south-east elongation of a high. Wind directions give no satisfactory explanation to the map of isallotherms.

On the 21st an axis of high pressures extends from Nova Scotia to Texas, and another in the West from Oregon to Texas. A northern low extends from Sault Ste. Marie and Duluth to Tennessee and Kansas.

Such pressure distributions give no satisfactory explanation of the maps of thermoterons for October 19th to 20th and 20th to 21st, nor do the "weather conditions" as given on the daily weather maps of these days.

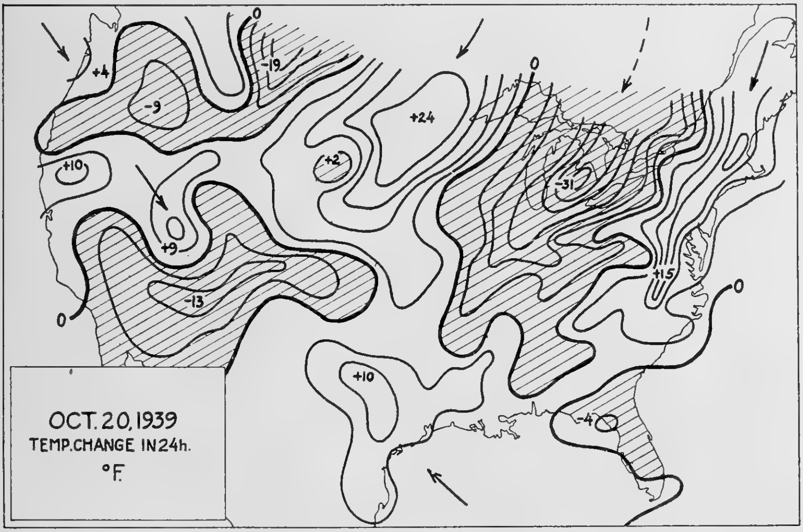

FIG. 24.—Temperature differences, October 19-20, 1939.

The maps of terons show a striking difference between the western and the eastern States. On the second map (fig. 25) we notice a narrow, very elongated area of decrease of temperature, extending from New Orleans, or from Mexico, to Portland, Oreg., and farther north. This is the katoteron of the Great Lakes of the preceding map (fig. 24). It is not possible to explain such a narrow strip of negatives by modern theories, by admitting that there is a polar air mass in connection with the high, extending from Nova Scotia down to Corpus Christi on the weather map of October 21, nor the very elongated area of increase of temperature, observed from north of the Great Lakes down to Mexico, because farther in a northwestern direction we have again a wave of negatives and positives.

But the last northwestern anoteron has its axis turned toward the west, an axis similar to those of the southwestern States. There we have differences in plus at Los Angeles, Phoenix, El Paso, and negatives at Modena, Santa Fe, and Abilene; then again an area of increase of temperature extending from Salt Lake City to Oklahoma City; finally another axis of negative values from Portland, Oreg., to Pocatello, and farther east, from Denver to Kansas City. It is as though, in October, and because of the seasonal decrease of temperature, the increasing pressures over the North American continent would be the cause of the formation of temperature waves, in plus and in minus, advancing from the northwest toward the southeast

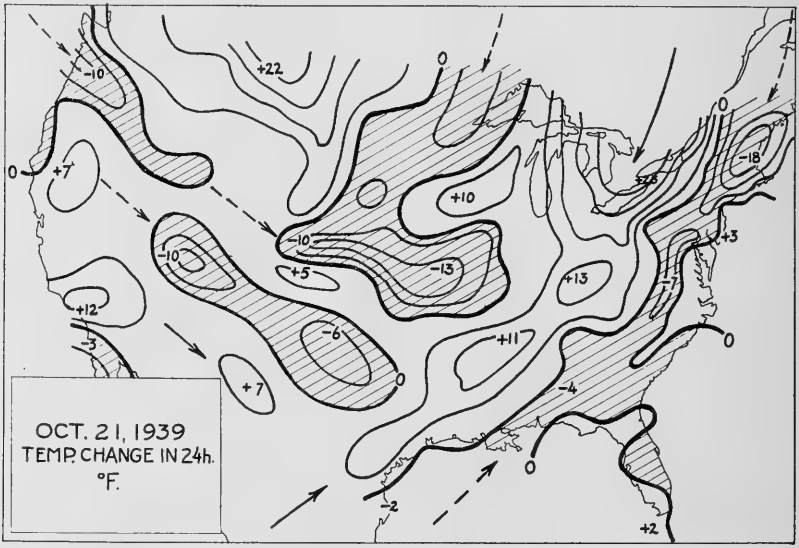

FIG. 25.—Temperature differences, October 20-21, 1939.

and from the southwest or the south toward the northeast or the north. If such is really the case, as comparisons with other maps suggest, the steps in fall of pressure would be the result of a counteraction against an exaggerated continental seasonal increase of pressure, just as it is in central Asia (fig. 23).

But all this appertains to the lowest part of the troposphere, possibly the practosphere only. What of the changes of temperature, as they are recorded on figure 25? Should they be exclusively the result of the interchange of tropical and polar air masses or is there another way to explain such contradictory terons as those of October 21, terons extending practically northeast-southwest and northwest-southeast?

A purely hypothetical explanation may be accepted simply to help coordinate the questions to be answered. Adam Kochański called the columns of ascending air topped by *Cu* clouds, "chimneys." A glider should glide from chimney to chimney and go up by jumps. Each day such air chimneys have a certain geographical distribution. Besides, the areas of good gliding do not vary at random, from day to day, but seem to be located according to certain definite zones. Airways of best gliding exist.

Suppose now that the discharge of air masses from an area of high pressure, such as the Pacific center of action, is characterized by discontinuities (fig. 26)—let us say, by concentric zones of predominating ascending and predominating descending air chimneys. This would occur in the practosphere. Higher up, in the lower or

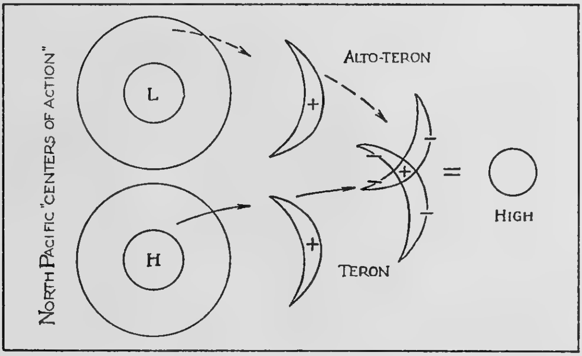

Fig. 26.—The formation of a high.

upper troposphere, air currents of opposite direction would transport air masses toward the center of high pressure, as recorded at sea level. The air displacements, high up and low down, may compensate each other, or they may sum up. Different rhythms of discharge may exist.

On the map during the months September to January, from the Asiatic center of high pressure, we should observe a transport of air masses toward the permanent Aleutian low; from there displacements on top, across North America, toward the permanent highs of Bermuda and the Azores; from the Hawaiian center of high pressure, at the bottom, a tendency of outgoing baroterons toward the Icelandic low.

In the stratosphere another system of circulation should prevail: from the Tropics toward the north, with a tendency of descent of the tropopause and a superposition, above the lower stratosphere of high latitudes, due perhaps to predominating descending air currents.

To sum up, the hypothesis should be that, besides the continental effect, three systems of waves would be distinguishable in the United States: low, the Hawaiian; higher up, the Aleutian; and highest of all, the tropical. Lows and highs would be the results of superposition. The active factors would be the seasonal effect of change of temperature distribution and the solar rhythms of radiation.[31]

16. ALTOTERONS

The maps of differences, from day to day, of the temperatures observed at different altitudes show that, at least up to 17 km., there are waves of increase and decrease. The altoterons for given altitudes may extend crosswise to those of lower altitudes. Evidently, certain directions of displacement as well as changes of altitude should be observed. Of the maps traced for October 1939 those of the 18th to the 24th, corresponding to the cited solar-constant data, will be described.

As there is a difference of about 7 hours between the observations of the morning weather maps and those of the upper-air data, the surface isallotherms for the 20th and 21st of the night observations (figs. 29, 30) compare well enough with those of the detailed morning maps (figs. 24, 25).

The maps of upper-air data are evidently less accurate. But the number of sounding stations is just sufficient to give a general idea of the distribution of altoterons and, in particular, the directions of elongation of these waves of increase and decrease of temperature.

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[31] To these hypothetical generalizations we should add a most interesting hypothesis of G. C. Simpson. In a paper on terrestrial radiation published in 1928 (Mem. Roy. Meteorol. Soc., vol. 3, No. 21, 1928) Simpson writes: "We thus arrive at the result that the cloud amounts on the three planets Mars, the Earth and Venus are in the same relative order as the intensity of the solar radiation at their positions, which supports the suggestion that cloud amount plays a predominating part in adjusting the balance of incoming and outgoing radiation in an atmosphere containing water vapor. It is interesting to consider in further detail what would happen to the earth's atmosphere if solar radiation increased at all appreciably. As already stated, the first effect on an increase of solar radiation would be an increase in the temperature differences between the equator and the poles; but it would also be accompanied by an increase in the temperature difference between the sea and the land. In consequence there would be an increase in the activity of the general circulation of the atmosphere; in particular there would be stronger monsoons, and the cyclonic depression of middle latitudes would be intensified. The increased circulation and the increased temperature would lead to increased cloud amount and increased precipitation. . . . ." As for the seasonal or even monthly anomalies, Simpson's hypothesis could be verified.

A comparison of maps on which the altitudes of the tropopause have been inscribed, with those of altoterons, shows that most probably there is no correlation. In other words the same change of temperature from one day to the following day may affect upper tropospheric as well as lower stratospheric air masses.

For example, on the 17th the tropopause was at an altitude of 18 km. in San Antonio, and at an altitude of 12 km. in Bismarck, while the maps of altoterons (fig. 27) show that both stations belonged, at an altitude of 13 km., to the same wave of increase of temperature extending northwest southeast.

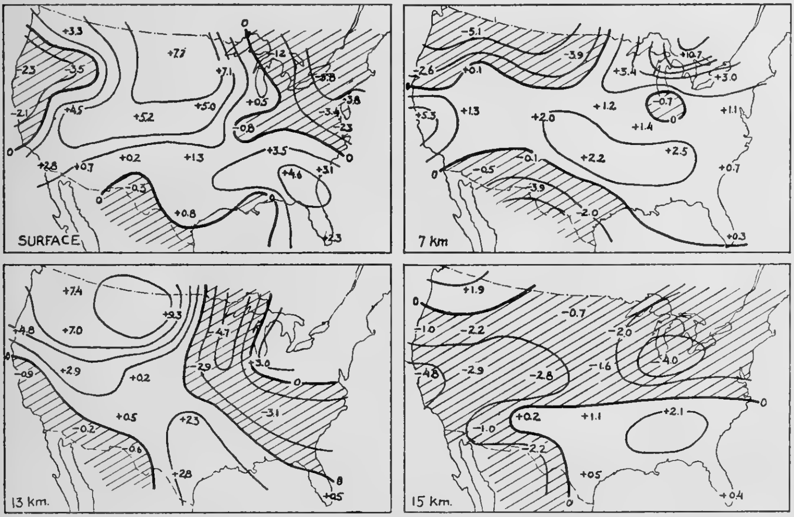

FIG. 27.—Altoterons, October 17-18, 1939.

On the 18th the same altitudes of the tropopause may be noticed. But on that date the upper tropopause was also observed in Bismarck, as well as in Spokane and Sault Ste. Marie. The altitudes are: San Antonio, Oklahoma City, Miami, 18 km.; Albuquerque, Omaha, Atlanta, 17 km.; Spokane, Boise, Bismarck, 16 km.; and Sault Ste. Marie, 15 km. Going north the altitude of the upper tropopause went down 3 km. The altitude of the lower tropopause also went down: Albuquerque 14 km., Denver 13 km., Bismarck 12 km.

Such a regularity of distribution of altitude is far from being the rule. For example, on the 21st the altitudes of the lower and upper tropopause observed at Sault Ste. Marie, Omaha, and Denver were, respectively, 10, 12, 14, and 17, 15, 17. A special study of the variations of altitude of the upper and lower tropopause, and their extent north and south, would be useful. As for an eventual correlation with solar-constant data, the selected dates give no satisfactory information.

A comparison of the maps of isotherms for different altitudes leads to several interesting conclusions.

First of all, at an altitude of only 3 km. the distribution of the altoterons may differ greatly from the distribution of the terons observed at the earth's surface. A tendency of similarity may, however, still be observed at an altitude of 4 km., as on October 21st (fig. 30) and to a certain extent on the 23rd (fig. 32). The maps for

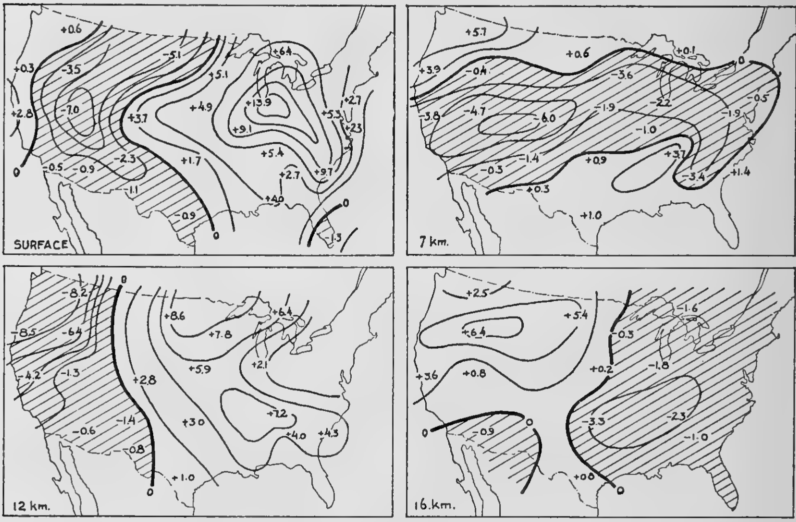

FIG. 28.—Altoterons, October 18-19, 1939.

the 20th (fig. 29) show at an altitude of 5 km. a reversal in plus, across the States, in place of decreasing temperatures at the earth's surface; at an altitude of 11 km., on the contrary, the maps are more or less similar.

Then, comparing for each day maps of isallotherms drawn for different altitudes, we see characteristic changes in the direction of elongation of the altoterons—for example, the 18th between 7 and 13 and 13 and 15 km. (fig. 27), and the 23rd between 11 and 14 km. (fig. 32). Finally, we see elongations of one system of waves across the States, intercrossings higher up, and above predominance of an opposite direction.

A comparison of the maps for given altitudes from day to day shows that besides the prevailing northwest-southeast and southwest-

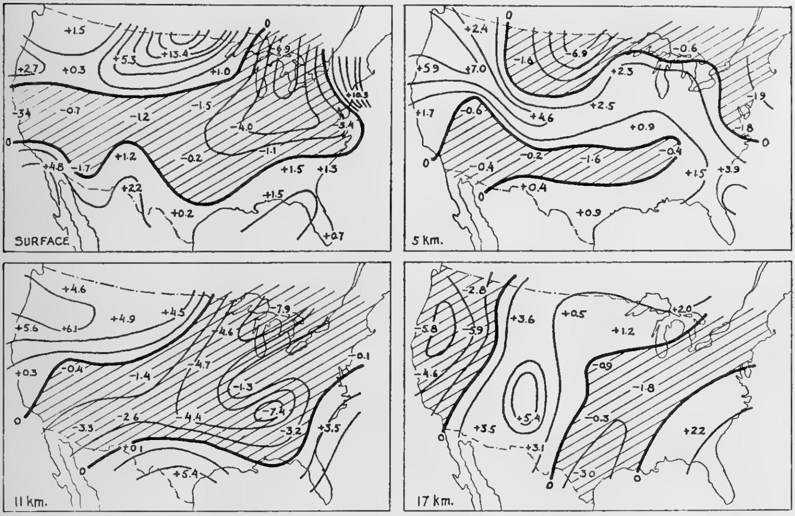

FIG. 29.—Altoterons, October 19-20, 1939.

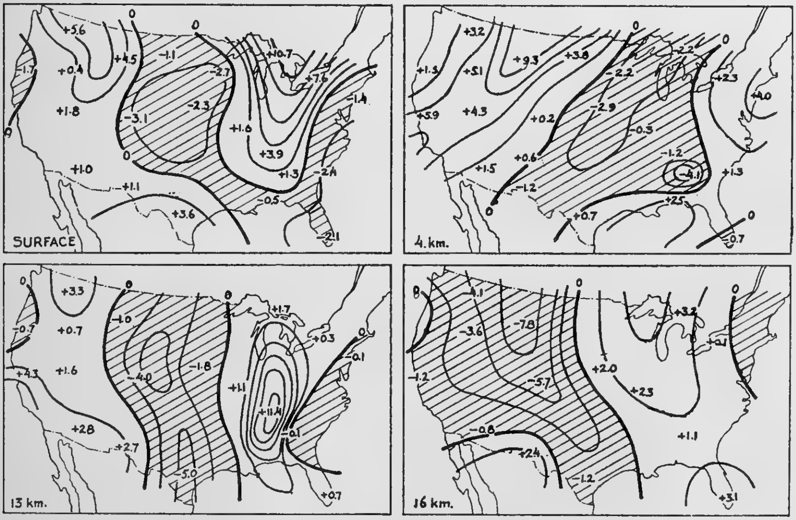

FIG. 30.—Altoterons, October 20-21, 1939.

northeast directions of displacement, a north-south displacement can also be discerned at an altitude of 9 km. on the 18th, 19th, and 20th.

It is difficult not to draw the conclusion that if this entire system of day-to-day temperature changes, extending up to altitudes of the upper stratosphere, works under the influence of the intensity variations of solar radiation, such should also be the first cause of all weather changes and of all temporary climatic anomalies as well.

But the upper atmospheric temperature changes from day to day form a complicated system of variations. A temperature decrease at a given altitude may be due to a predominating ascent of air masses

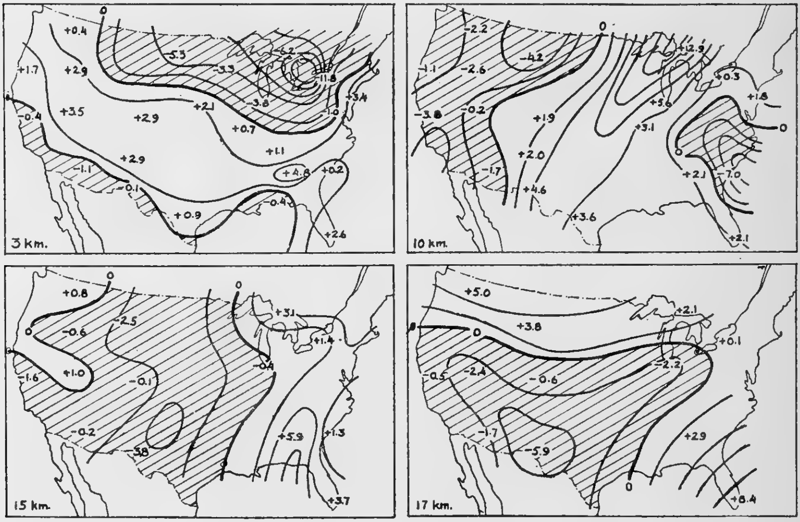

FIG. 31.—Altoterons, October 21-22, 1939.

as well as to a horizontal atmospheric exchange of an air mass coming from a colder region.

The ascending and descending air currents have been studied extensively by Kochański and Wiszniewski.[32] The following citation summarizes the results they obtained:

Utilisant les données de 84 sondages effectués à Leipzig et à Dresde, durant les années 1926 à 1929,[33] principalement pendant la saison froide, nous avons

[32] Kochański, Adam, and Wiszniewski, Wacław, Sur les courants verticaux dans les portions supérieures de la troposphère et dans la stratosphère. Inst. Geof. i. Meteorol., Uniw. Lwów, Kom., vol. 8, No. 104, pp. 257-276, 1936.

[33] Ergebnisse der Registrierballonfahrten ausgef. vom Geophys. Inst. Univ. Leipzig und Sächs. Landeswetterwarte, Dresden, in den Jahr. 1926-2927 und 1928-1929.

calculé les vitesses ascentionnelles des ballons, par niveaux de 250 m. . . . . Recherchant les causes ayant pu produire de forts courants ascendants dans les régions élevées de l'atmosphère, nous avons étudié les résultats des ascensions de l'année internationle 1923.[34] Dans 30 p.c. des cas envisagés nous avons constaté une forte instabilité entre 5 et 10 km. La Fig. 4 renseigne quelques exemples d'une telle instabilité, ayant pu, dans le cas de l'ascension du 20 october 1923 provoquer des courants verticaux atteignant 14 m. par seconde, à l'altitude de 8 km. (Vitesses calculées à l'aide de la formule de Linke).[35] . . . . L'instabilité observée aux grandes altitudes peut être de la même grandeur que celles observées dans la région des *Cu* et des *Str-Cu.* L'aspect des *Ci* en flammes peut donner des renseignements concernant les épaisseurs des couches d'instabilité. D'après les observations faites à Lindenberg,[36] les *Ci* ont fréquemment des épais-

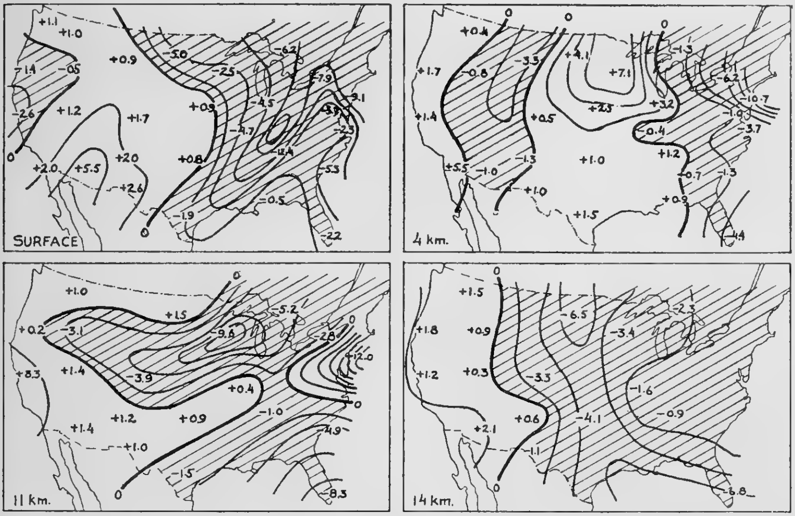

FIG. 32.—Altoterons, October 22-23, 1939.

seurs dépassant 2000 m. et atteignant même 3600 m. Il est difficile de prouver que les courants verticaux observés dans la stratosphère, sont dûs à des cellules applaties de turbulence (Poncelet),[37] ou s'ils sont des champs de courants ascendants et descendants des entonnoires et des proéminences de la tropopause (Palmén).[38] Se basant sur les résultats obtenus on pourrait distinguer, au moins

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[34] Comm. Internat. de la Haute Atmosphère. C. R. des jours internationaux, 1923. I, II, III, et IV partie. Cambridge, 1927.

[35] Linke, Franz, Zur Vertikalbewegung isolierter Luftmassen. Meteorol. Zeitschr., vol. 45, No. 7, p. 259, 1928.

[36] Scholtz, C., Wolkenmessungen mit dem Entfernungsmesser. Arb. Preuss. Aeronaut. Obs. Lindenberg, vol. 14, Wiss. Abh., pp. 158-161, 1922.

[37] Poncelet, Lucien, Sur des mouvements de turbulence dans la stratosphère décelés par un ballon-sonde. Acad. Roy. Belgique, Bull. Cl. Sci., Ser. 5, vol. 21, No. 2, pp. 195-215, 1935.

[38] Palmén, E., Aerologische Untersuchungen der atmosphärischen Störungen. Mitt. Meteorol. Inst. Univ. Helsingsfors, No. 25, pp. 1-65, 1933.

jusqu'à 15 km. d'altitude, cinq étages jouant un rôle actif dans les mouvements verticaux, et quatre étages passifs. Les étages actifs sont:

1) *Cu, Str-Cu, Nb,* 0-1,5 km.
2) *Al-cu,* 4 "
3) *Ci-Cu,* 7 "
4) Tropopause 11-12 "
5) Stratosphère au-dessus de 14 km.

Les étages passifs s'observeraient entre les niveaux des *Cu* et des *Al-Cu,* entre les *Al-Cu* et les *Ci-Cu,* puis au-dessus des *Ci* et des *Ci-Str,* et enfin dans la stratosphère, au-dessus et au-dessous du niveau actif No. 4.

Such a subdivision of the atmosphere into floors of greatest intensity of the ascending air currents does not simplify the problem of the effects of the active factor—far from it.

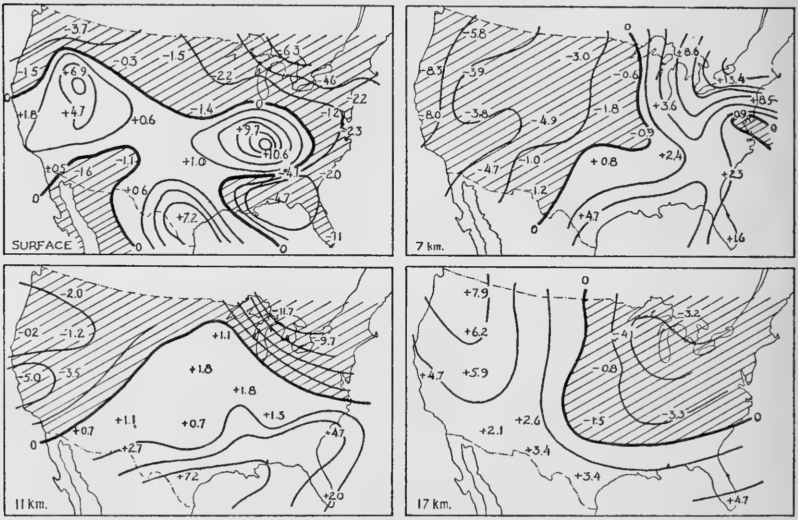

FIG. 33.—Altoterons, October 23-24, 1939.

Cloud levels are evidently indicators of rising air currents. Regarding *Cu* clouds, the earth's surface should be the active factor or the level of direct reaction to solar radiation. The tops of these low clouds form another floor of reaction. They may lead to the formation of *Al-Cu* clouds and so, step by step, up to the highest clouds. From an airplane flying over a *Str-Cu* the author once saw large domes more or less regularly distributed about 5 to 10 km. apart. It may be that they represented undeveloped *Cu-Ni* clouds. Frequently the *Str-Cu* is characterized by discontinuities.

Higher up, the *Al-Cu* clouds may extend from one horizon to the opposite horizon in the form of elongated bands. Between such cloud zones the sky will be clear. Instead of air chimneys, topped by *Cu* clouds, we have now inclined sheets of ascending air and, in consequence, cloud waves.

Still higher, the flames of *Ci* clouds show that in the upper troposphere the ascending sheets extend high above the altitudes of the formation of these clouds of ice crystals.

The lows are usually associated with *Ci* and *Ci-Str* clouds. The *Cu-Ni* or thunderstorm clouds are associated with inflexions of the isobars (Durand-Gréville). Are these inflexions of isabars the cause of the thunderstorms or thunderstorm fronts advancing eastward, or does the barometer simply register the passage of these complex columns of ascending air masses, best studied on statoscopic registrations?

And what of the lows? The isobars traced for an altitude of 6 km. most frequently have nothing in common with those of the weather maps, reduced to sea level. This fact alone might seem sufficient to draw the conclusion that what happens up to about 3 km. of altitude (in the practosphere) is independent of the changes occurring higher up—a conclusion not to be rejected unconditionally—or we may be led to imagine that the highs and lows of the bottom strata of the atmosphere and the interchanges of air masses down below are due to the temporary changes, high above, producing step by step regionally up-rising or down-falling air currents. Having that point of view in mind, even a most superficial study of the American radiometeorographic tables of observations is instructive.

Comparing the data, from date to date, one notices that in many instances a temperature difference in plus or minus extends from the earth's surface up to an altitude of 10 or even 15 km. This is so far at least 10 percent and perhaps as much as 20 percent of day-to-day differences. Frequently, however, the change of sign occurs at 3 or 4 km. and sometimes lower down. Further, taking the range of variability for the different altitudes, month by month, we find for example at Miami for September 1939 a maximum of 12° at 14 km., while at sea level the difference between the highest and lowest observed temperatures was only 5° C. The figures for October are: 11 km. 19°3, surface 5°4. The maxima occur at 11 to 17 km. Such is not the rule for the winter, because then the differences may also be very great from sea level up to 2 km.

At Juneau and Fairbanks, Alaska, a very pronounced minimum of variability occurred at an altitude of 9 km. in February 1940. This minimum of variability for that particular month may also be observed for the altitudes of 9 to 11 km. at Oakland, for 9 km. at Sault Ste.

Marie, 9 to 11 km. at Omaha, 10 km. at Lakehurst, 11 km. at Oklahoma City, and 9 to 11 km. at Miami, and a maximum of variability higher up.

Such facts seem to show that in the United States, and Alaska as well, the exchange of air masses above an altitude of 11 km. should be considered the active factor and that the changes of weather are dictated from above, step by step, but that often, and more often in particular regions, the extra terrestrial impulses of increased activity extend directly to the earth's surface, producing changes of temperatures there as well as above.

SUMMARY AND CONCLUSION

During the years 1926 to 1930 a close correlation between the variations of solar-constant data and the areas of faculae seems to exist.

The mean duration of the variations was found to be 6½ or 7 days. The solar-radiation minima and maxima precede those of faculae. The extent of faculae is therefore nothing but a slightly belated indicator of the changes of intensity in solar radiation and not the cause of the solar-constant variations. A retardation of the temperature changes observed at different stations for the selected means of maxima and minima of radiation seems to be the rule. At mountain stations in the Alps the retardation is less going up. A direct hit as well as an after effect was observed at several meteorological stations. Evidently, all available data should be used in order to find out whether the regions of direct hit correspond to particular meteorological conditions or if they are more or less permanent.

Pressure waves are presumably due to temperature changes. In the Antarctic regions, at Framheim, the mean duration of these waves is 6½ to 7 days, surely a striking similarity to the mean duration of the variations of solar radiation. If such pressure waves originate on the Antarctic continent, other centers of origin must exist, as well as regions of most frequent intercrossings.

Overlapping 10-day means give the duration of surges, or brachypleions. The brachypleions of Batavia (fig. 5), under the Equator, are the product of two opposite tendencies: Asiatic and Australian seasonal maxima and minima of pressure. In the course of time, changes of duration of surges and of pressure waves must occur. Those observed at Warsaw (fig. 4) may serve as example. It is not necessary to add how extensive the researches on pressure waves should be, in order to make sure whether they really are due to solar impulses.

The geographical distribution of temperature and pressure changes from day to day has been considered in section 4. The waves have been called terons, either baroterons or thermoterons. Anoterons are the areas of increase, katoterons those of decrease, of pressure or temperature. A typical example of bipolar baroterons is given in figure 6.

Intercrossings of terons occur frequently. The best way to explain intercrossings of baroterons is to suppose a superposition of two pressure changes, at different altitudes, progressing crosswise. Therefore, two or more systems of pressure and temperature changes, one above the other, should be observed. That this is the case is shown plainly by the examples given in section 5. They refer to American radiometeorograph observations corresponding to the solar-constant maximum of August 11, 1939.

The annual variations of the Batavia upper-air data of 1910-1915 show an increase of amplitude with increasing altitude and opposition of seasonal maxima and minima of temperature recorded at 11 and 17 km. (fig. 8). In section 6 the Batavia observatory data were taken mainly to show the important role of the stratosphere in annual variations—possibly also in changes occurring from day to day under the influence of solar-radiation anomalies.

In middle latitudes two stratospheres exist: a tropical above and a polar stratosphere beneath (figs. 10, 15).

The altitudes of the lower tropopause are higher during the summer than during the winter months (figs. 16, 17).

Tables of lapse rates of monthly means should be compared. Table 5, for example, shows that at Sault Ste. Marie from July to October, 1939, only the upper tropopause was observed, whereas from November 1939 to July 1940 both a lower and an upper stratosphere were observed.

The diagrams of lapse rates show that a distinction should be made between a lower troposphere, with increasing lapse rates with altitude, and an upper troposphere (fig. 20). Besides, the variations observed in the first 2 or 3 km. of altitude in the practosphere, characterized by important inversions particularly during the winter months (fig. 21), are evidently of the greatest importance in changes of weather.

These facts show that a reaction to any solar-radiation change may be very different high up from what it will be at the earth's surface, and that these different variations may influence each other.

The presence or absence of certain cloud levels at different altitudes is evidently of prime importance.

Comparing maps of temperature changes from date to date (figs. 24, 25), we find intercrossings of thermoterons. These areas of increase and decrease may persist following different directions of displacement.

The inflexions of the curves of radio soundings differ. In consequence, the maps of altoterons (figs. 27-33) may indicate certain levels of characteristic changes in the geographical distribution of the areas of increase and decrease of temperature. All these changes seem to be correlated with solar-radiation changes. High above all cloud horizons it is only the direct hit of a solar-constant maximum and minimum that should be observed. But this is not so, at least up to an altitude of 17 km., where stratospheric altoterons can still be observed.

Are stratospheric altoterons due to migrations of air masses or are they exclusively the effect of adiabatic changes? To answer this question, it will first be necessary to make sure through further research whether the altoterons of very high altitudes really are waves originating in the Tropics under the impulses of solar-radiation changes.

To sum up, all the evidence obtained so far leads to the conclusion that solar variation is a weather element of wide and complex influence. An effort should be made to construct a radio pyrheliometer. Everyday measurements, as high as possible, should be made with such an instrument, because continuous records of the variations of solar radiation would not only serve to elucidate problems concerned with stratospheric changes of temperature, but also would be of practical use in weather forecasting.[39]

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[39] At Omaha, on July 11, 1914, L. B. Aldrich succeeded in obtaining a balloon pyrheliometric record of solar radiation. See Abbot, C. G., Fowle, F. E., and Aldrich, L. B., New evidence on the intensity of solar radiation outside the atmosphere. Smithsonian Misc. Coll., vol. 65, No. 4, p. 48, 1915.

Dr. Brian O'Brien has been earnestly working on the problem of a radio perhyliometric device for several years, and has made great progress in overcoming the many difficulties.

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BEETLES OF THE GENUS HYPERASPIS INHABITING THE UNITED STATES

(WITH 6 PLATES)

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Department of Zoology, Columbia University

(PUBLICATION 3642)

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BEETLES OF THE GENUS HYPERASPIS INHABITING THE UNITED STATES[1]

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(With 6 Plates)

Hyperaspis is one of the largest and least-known genera of the family of ladybird beetles (Coccinellidae). Its representatives are economically important as predators on scales and other insect pests. They can be bred in the laboratory and may prove to be favorable material for experimental work. The center of dispersal of *Hyperaspis* is in Central and South America. The fauna of the United States is relatively rich, especially in the South and Southwest, but only a few stray species have found their way into Canada and the Old World. *Hyperaspis* appears to be a young genus in which the processes of species differentiation are in progress.

Most of the available information on the North American *Hyperaspis* must be credited to Thomas L. Casey, who is the author of more than half of the described species. Casey was in the habit of treating as species even insignificant structural and color variants. That Casey recognized the provisional nature of many of his "species" is shown by the following statement in his Revision of the American Coccinellidae (1899): "Although it is possible that many of the forms . . . . may prove to be more properly subspecies of a few type forms, which could be determined by future collecting and careful investigation, they are at least apparently worthy of distinctive names for future reference, and that is all that can be positively affirmed at present. . . . ." The present paper attempts a critical evaluation of the relationships between various representatives of the genus *Hyperaspis* on the basis of more abundant material than that available to previous workers. The results arrived at are still largely tentative, especially since the fauna of *Hyperaspis* of Mexico and Central America could not be examined. This is important because many

[1] This is the fourth contribution to be published by the Smithsonian Institution under the Thomas Lincoln Casey Fund.

species of *Hyperaspis* reach their northern limits near the southern boundary of the United States, and the main parts of their distributions, as well as those of their closest relatives, are outside the territory the fauna of which has been studied.

The study is based primarily on the collections of the United States National Museum (later referred to as NMC), lent to the writer through the courtesy of Dr. E. A. Chapin. In addition, the collections of Thomas L. Casey (abbreviated below as CC) containing his types, of F. T. Scott (SC), the California Academy of Sciences (CASC, including those of Dr. E. P. Van Dyke and E. P. Van Duzee), P. H. Timberlake, Charles W. Leng, The Citrus Experiment Station of the University of California, San Diego Museum, University of Idaho, University of Minnesota, Illinois State Natural History Survey, and Oregon State College have been examined. To the owners and guardians of these collections the writer wishes to express his sincere appreciation of their courtesy; an especial acknowledgment must be made of the help and advice received from Dr. E. A. Chapin.

Since the distinguishing of species and races of *Hyperaspis* is still based to a large extent on their color patterns, drawings of most of the species are given in plates 1-3. It is believed that these drawings, despite their crudity, will be of much service to those who will use this paper in their work of determining *Hyperaspis,* and certainly even such drawings save many words in the description of the respective species. In the list of the localities in which each species is known to occur only those localities are included from which some specimens have been personally examined by the writer; a few exceptions from this rule are explicitly stated to be such. The names of the collectors and of the museums in which the specimens are found are indicated only for rare species and for particularly interesting records.

Genus HYPERASPIS Redtenbacher (1843)

Medium-sized to small representatives of Coccinellidae. Body from elongate-oval to rounded-oval, from moderately convex to subhemispherical, upper surface always glabrous, the abdomen pubescent in a few species. Head not dilated laterally, base of the antennae exposed, eyes without emargination, rather finely faceted, frequently greenish in color. Antennae (pl. 6, fig. 167) short, 11-jointed (the two last joints almost fused), the apical portion fusiform. Mandibles (pl. 6, fig. 169) bifurcate at the apex, with a bicuspidate tooth at base, and a finely ciliate membrane internally. Maxillae (pl. 6, fig. 170) small but with a strongly developed maxillary palpus; the last joint of the palpus securiform, but not more than twice as large as the two preceding joints. Mentum obcordiform, labium membranaceous at the apex, covered with very minute ciliae, apparently of a sensory nature; labial palpi small, two-jointed. Pronotum and the elytra tightly fitted to each other, scutellum large, elytral epipleurae narrow, with distinct foveae for the reception of the knees. Prosternum with two carinae more or less widely separated at base, converging cephalad, fused together before reaching the anterior margin of the segment, and usually continued forward as a single line. Abdomen with six clearly visible sternites, the first of which carries the femoral (metacoxal) lines, the exact shape of which varies from species to species. Legs short, tibiae slender, not spinose, anterior ones with an external plate delimited by an oblique suture, tarsal claws with a tooth at base (pl. 6, fig. 168) which is rudimentary in some species.

Coloration predominantly black (in the following text the body parts, the color of which is not stated, are assumed to be black, except that species having light-colored lateral portions of the pronotum have also light pronotal epipleurae, and those having light humeral or marginal spots or marginal vittae on the elytra have also correspondingly colored elytral epipleurae). Coloration of the head and the pronotum is usually sexually dimorphic, being lighter in the males than in the females. With very few exceptions, all the tremendous variety of the elytral patterns of the North American *Hyperaspis* (pls. 1-3) may easily be derived from a single type, or basic, pattern, consisting of five light spots on the black background of each elytron (pl. 1, fig. 31). Among these spots, the one lying on or near the external margin posteriorly from the humeral angle of the elytron is termed the humeral spot; that lying outward and posteriorly from the scutellum is the basal spot; that located on or near the external margin near the middle of the length of the latter is the marginal spot; the discal spot occupies the middle of the elytron; the apical spot lies in front and outward from the apex. These spots may disappear or fuse in various combinations, intraspecific variations being common. The position of the spots relative to each other and to the fixed points of the elytron (suture, base, apex, scutellum, etc.), and to a certain extent their relative sizes, are, on the contrary, very constant within a species but greatly variable from one species to the next; certain correlations between the position of the spots and the shape of the elytron and the body may be discerned.

Both the dorsal and the ventral surfaces of the body are covered with punctures, the density and the strength of which vary from species to species. In general, the punctures on the head are finer than those on the pronotum, and those on the pronotum are finer than those on the elytra. On the ventral surface the punctures tend to be especially dense and strong on the sides of the metasternum and mesosternum and on the middle part of the first abdominal sternite; the space enclosed by the femoral lines is frequently almost devoid of punctures. The interstices between the punctures may be polished or alutaceous.

Male reproductive organs (pl. 4, fig. 104) consist of six-lobed testes (T), a short vas deferens (VD) enlarged to form the seminal vesicles (SV), two pairs of accessory glands (AG) one of which is much shorter than the other, a long ejaculatory duct (DE), an extrusible sipho (aedeagus, sometimes misnamed penis, S), basal plates (BP) to which the true penis is attached (median lobe, P), paired paramera (lateral lobes, PA) carrying a tuft of bristles distally and sensory pores proximally, and trabes (TR, tegminal strut). The penis is always asymmetrical, and its shape varies greatly from species to species; paramera and basal plates are also variable, while the sipho and trabes are rather uniform.

Female reproductive organs (pl. 4, fig. 106) consist of ovaries (OV) with 10 to 12 egg-strings, rather short oviducts (OD), a conical bursa copulatrix (BC), a complex spermatheca (RS) with an accessory gland (GR), and the chitinized parts of the ninth sclerite (9ST) and tenth tergite (10T) densely covered with short but stubby hair. The spermatheca (pl. 6, figs. 157, 158, 162-166) is divided into a thimblelike basal portion and a more or less retort-shaped distal capsule united with the basal portion by means of a very slender tubular connecting duct. The basal portion has a chitinized appendix the size of which varies greatly from species to species.

I. LEVRATI GROUP

This group includes a large number of species living in Central and South America, but only two are known to occur in the United States. It is a part of the Mulsant's genus *Cleothera,* which all the more recent authors consider not to be a natural unit, and therefore treat as a synonym of *Hyperaspis.* The elytral pattern consists of a marginal vitta resulting from a confluence of the humeral and marginal spots, and of basal, discal, and apical spots. Male genitalia have a very short, very asymmetrical penis, large basal plates, and short and broad paramera.

HYPERASPIS LEVRATI (Mulsant)

Plate 2, Figure 62

Cleothera levrati Mulsant, 1850, p. 613.
Hyperaspis levrati Gorham, 1894, p. 192.—Schaeffer, 1905, p. 145.
Brachyacantha metator Casey, 1908, p. 413.—Leng, 1911, p. 8.

Rounded oval, strongly convex. Head whitish yellow in males, black in females. Pronotum distinctly longer at the middle than on the sides, in males with pale yellow stripes on the anterior and lateral margins, the lateral stripes being wider than long, in females with lateral stripes only which are longer than wide. Elytral spots pale yellow; the marginal vitta extending from the base to two-thirds of the length of the margin, its posterior part (corresponding to the marginal spot) much wider than the anterior one, basal and discal spots rounded, the former smaller than the latter, apical spot transversely oval. Punctulation rather dense and strong. Mouth parts and legs yellow, femora brown in females, sides of the abdomen usually piceous. Prosternal carinae fused in front of the coxae; femoral lines almost touching the posterior margin and running subparallel to it, their outer parts not reaching the sides of the segment. Penis (pl. 4, fig. 111) much shorter than the paramera, the latter broad, spoon-shaped, densely covered with hair distally and with sensory pores proximally. Basal portion of the spermatheca large, with a small appendix, the capsule spherical, the connecting duct rather short and broad.

Length of the body, 2.2-2.6 mm.; width, 1.7-2.0 mm.

Geographic distribution.—Localities as follows:

Wyoming: Bosler (P. C. Ting, NMC).
Colorado: Canon City (NMC), Cortez (Th. Dobzhansky).
Texas: Del Rio (type of *Brachyacantha metator*, CC).
Arizona: Cochise County, Palmerly, Santa Rita Mountains, Huachuca, Tucson, Winslow.
Mexico: (exact locality label unreadable, CC).

Remarks.—Casey considered this species to belong to the genus *Brachyacantha*, but later has himself placed it in *Hyperaspis*, without apparently realizing its identity with *levrati* (Mulsant). The specimens from Wyoming and Colorado are larger and have relatively smaller spots than those from more southern States. This northern race may possibly deserve a subspecific name, but I prefer to await further material before deciding this issue.

HYPERASPIS REVOCANS REVOCANS Casey

PLATE 2, FIGURE 63

Hyperaspis revocans CASEY, 1908, p. 419.

Broadly oval, somewhat obtusely rounded behind, convex. Head and mouth parts yellow in both sexes; pronotum yellow with a large black semicircular spot on the base in males, black with yellow lateral and anterior margins in females. The elytral pattern variable: marginal vitta as in *levrati* but equally wide anteriorly and posteriorly and somewhat narrower in the middle; apical spot very large, sometimes confluent with the marginal vitta; basal and discal spots much smaller than the rest but broadly confluent with each other, forming an oblique vitta extending from the vicinity of the scutellum to past the middle of the length of the elytron; in some specimens this vitta is confluent with the marginal one and with the apical spot, giving yellow elytra with a black vitta on the suture expanded at one-third and two-thirds of the length and a wedge-shaped black vitta extending from the base to two-thirds of the length and somewhat more remote from the suture than from the margin. Punctulation dense but rather fine, interstices polished. Mouth parts, legs, and abdomen piceous yellow, femora infuscate in females, in some specimens the entire under side piceous. Prosternal carinae fused not far from the anterior margin, femoral lines more evenly arcuate than in *levrati*. Penis (pl. 4, fig. 115) shaped like a shark's tail fin, only slightly shorter than the paramera, the latter very short, basal plates relatively very large. Female genitalia unknown.

Length of the body, 1.5-1.9 mm.; width, 1.2-1.5 mm.

Geographic distribution.—Localities as follows:

Utah: St. George (type, CC, topotypes in C. W. Leng's collection).
Arizona: Phoenix (SC), Hot Springs (NMC), Yuma (NMC).
California: San Diego County, La Puerta (CASC).

Remarks.—This species is related to *levrati* Mulsant, but the differences between the two amply justify their specific distinction; although they have never been found in the same locality, their ranges probably overlap.

HYPERASPIS REVOCANS OCCIDENTALIS, new subspecies

PLATE 1, FIGURE 37

Somewhat less broadly oval than the typical *revocans*, punctulations of the pronotum and the elytra finer, interstices strongly polished. Elytra with a yellow marginal vitta which is narrower than in the type form, a rather large apical spot, a small rounded or comma-shaped basal spot, and no trace of a discal one. Genitalia of the male identical with those of the typical form.

Length of the body, 1.8-2.2 mm.; width, 1.4-1.6 mm.

Type.—In collection of F. T. Scott.

Paratype.—U.S.N.M. No. 54198.

Geographic distribution.—Locality as follows:

California: Kettleman City, 3 ♂♂ and 2 ♀♀ including the type (on *Artiplex* infested by a species of *Orthezia*, F. T. Scott, SC).

II. OCTONOTATA GROUP

Only three species of this group occur in the United States, all their relatives being native to Central and South America. The elytral pattern consists of a humeral, marginal, apical, and discal spots, the first two sometimes fused to form a marginal vitta. The discal spot located in front of the middle of the length of the elytron. Penis knife-shaped, about as long as the paramera. The capsule of the spermatheca retortlike, gradually passing into the connecting duct.

HYPERASPIS OCTONOTATA Casey

PLATE 2, FIGURE 53

Hyperaspis octonotata CASEY, 1899, p. 121.

Very broadly oval, somewhat obtusely rounded behind, strongly convex. In males the head, large subquadrate spots on the lateral, and a stripe on the anterior margin of the pronotum yellow, in females head black, pronotum with yellow spots laterally but without a stripe on the anterior margin. On the elytra, the humeral spot extending from the base to about one-fifth of the length, longer than wide, usually parallel-sided, abruptly terminated posteriorly; the marginal spot semicircular; the apical one rounded or transversely oval; the discal one rather small, somewhat oblique, oval or comma-shaped. Pronotum densely and rather finely, elytra less densely but only a little more strongly punctured, abdominal segments very densely and strongly so. Mouth parts and femora dark brown, tibiae and tarsi yellow, sides of the abdomen brown. Prosternal carinae short, fused only slightly in front of the coxae, femoral lines angular, touching the posterior margin of the segment at one point only. Penis (pl. 4, fig. 122) knife-shaped, one side nearly straight, the other straight basally but rounded toward the apex; paramerae long and slender, finger-shaped, basal plates rather short. The basal portion of the spermatheca about twice as long as wide, the appendix very short.

Length of the body, usually 2.4-2.9 mm.; width, 2.0-2.4 mm.; exceptional individuals considerably smaller.

Geographic distribution.—Localities as follows:

Texas: Brownsville, Esperanza Ranch, Round Rock, Del Rio, Sanderson, Davis Mountains.

Colorado: Canon City (NMC).

Utah: St. George (C. W. Leng collection).

Arizona: Phoenix, Wilcox, Graham County (on *Toumeyella mirabilis*), Benson, Cochise County, Palmerly, Tubac, Chiricahua Mountains, Oracle, Tucson (on *Toumeyella mirabilis*), Santa Rita Mountains, Huachuca Mountains, Miller Canyon.

California: San Francisco (SC), Santa Maria (on *Physokermes insignicola*), Santa Barbara (on *Physokermes insignicola*), Tulare County (a series of more than 100 individuals, on *Coccus pseudomagnoliarum*, SC), Sequoia National Park (SC), Kern County.

Mexico: Durango (CC), Chihuahua (on *Toumeyella mirabilis*, NMC), Ontagota Yaki Valley (on tree cotton, NMC).

Remarks.—Individuals from the coastal zone of California tend to have a somewhat larger size and to have the yellow coloration of the elytral spots replaced by a red. For the time being I see no need of giving this race a separate name.

HYPERASPIS BENSONICA BENSONICA Casey

Plate 1, Figure 3

Hyperaspis bensonica Casey, 1908, p. 418.

Broadly oval, strongly convex, pronotum short and broad, elytra obtusely rounded behind. In females head and pronotum black, in males head yellow with a transverse black fascia on the vertex usually covered by the margin of the pronotum, pronotum with the lateral and anterior margins narrowly yellow. Elytra with a yellow marginal vitta extending from the base to two-thirds of the length of the margin, strongly sinuate internally, the discal spot rounded or longitudinally oval, the apical larger than the discal one, transversely oval, in some specimens showing a tendency toward confluence with the marginal vitta. Punctulation of the pronotum dense and rather strong, that of the elytra both sparser and finer (in most other species of *Hyperaspis* elytra are punctured as strongly as, or stronger than, the pronotum), that of the under side very dense and strong, the space within the femoral lines has some shallow but very large punctures. Under side black or piceous, tibiae and tarsi yellow, mouth parts piceous or yellow. Prosternal carinae like those in *octonotata,* femoral lines evenly arcuate, only touching the posterior margin or running for a short distance parallel to it. Penis (pl. 5, fig. 136) rather broad at base, with a tubercle located on the convex side closer to the base than to the apex, narrowed distally. Female genitalia as in *octonotata*.

Length of the body, 2.1-2.6 mm.; width, 1.7-2.1 mm.

Geographic distribution.—Localities as follows:

Utah: Kanab (SC).
Colorado: Paonia, Canon City (NMC), Glenwood Springs (CASC).
New Mexico: Las Vegas Hot Springs, Santa Fe (NMC).
Arizona: Kaibab Forest, Wupatki, Grand Canyon, Wickenburg, Peach Springs, Ashfork, Phoenix, Mesa, Globe, Walnut, Oracle, Hot Springs, Littlefield (on *Pluchea sericea*), Williams, Cochise County, Palmerly, Benson, Santa Catalina Mountains, Tucson, Santa Rita Mountains, Nogales, Pinal Mountains.
Nevada: Glendale (on *Chrysothamnus paniculatus*, NMC).
California: San Luis Obispo County, Pinnacles National Monument, Santa Barbara, Mojave, Hesperia, Palmdale, Fort Tejon, Pasadena, Jacumba, San Diego, Palm Springs.
Mexico: Sonora Guaymas (NMC).

Remarks.—Casey believed this species to be a relative of *quadriocu-lata*, with which it has little in common except a similarity of the elytral pattern. It is a relative, though by no means a close one, of *octonotata*.

HYPERASPIS BENSONICA DISRUPTA, new subspecies

PLATE 2, FIGURE 52

Differs from the typical form by having the marginal vitta broken into separate humeral and marginal spots, the first of which is triangular and the second semicircular. The discal spot longitudinally oval (in one individual discal spot absent). Genitalia identical with those of the typical form.

Type.—In collection of F. T. Scott.

Paratype.—U.S.N.M. No. 54199.

Geographic distribution.—Localities as follows:

California: Kern County, 4 ♀♀ and 3 ♂♂ including the type (SC), Coalinga, 3 ♀♀ and 2 ♂♂, on juniper infested by a species of mealybug (SC), Pinnacles National Monument (CASC), San Luis Obispo County, 1 ♀ (SC), Lebec (CASC), Mount Lowe, 1 ♂ (Th. Dobzhansky).

Remarks.—This is a rather indistinct race of *bensonica* which is given here a name to prevent its confusion with *quadrioculata* subsp. *notatula* having a very similar elytral color pattern; the two species can be distinguished by the body shape which is more rounded and more convex in *bensonica*, and, of course, by structural characters. A tendency toward the breaking up of the marginal vitta into the constituent spots is noticeable in specimens of *bensonica* coming from California, and seldom in those from Arizona; such specimens constitute a transition between the typical *bensonica* and subsp. *disrupta.*

HYPERASPIS CHAPINI, new species

Plate 2, Figure 55

Broadly oval, strongly convex. In males head yellow with a transverse black stripe on the vertex, mouth parts brown, pronotum narrowly yellow on the anterior margin and with a yellow stripe which is from one and a half to two and a half times longer than wide on the lateral margin; in females head black, mouth parts dark brown, pronotum with a yellow stripe laterally which is from two and a half to four times longer than wide. Elytra with yellow marginal and apical spots only, the former lying slightly behind the middle of the length of the margin, semicircular or longitudinally oval, the latter rounded or transversely oval. Pronotum, elytra, and the under side rather densely and finely punctured, the punctures of the elytra only slightly, if at all, stronger than those on the pronotum. Legs black with brownish-yellow tibiae and tarsi in females, yellow with black hind femora in males, sides of the abdomen piceous in some individuals. Prosternal carinae short, femoral lines broad, semicircular, not quite attaining the posterior margin of the segment. Penis (pl. 4, fig. 110) much shorter than the broad paramera, strongly asymmetrical, resembling those of the species of the *gemma* group more than that of *octonotata.* The capsule of the spermatheca spheroidal, the connecting duct short, basal portion relatively large, with a small appendix.

Length of the body, 2.2-2.7 mm.; width, 1.7-2.1 mm.

Type and 33 paratypes.—U.S.N.M. No. 54200.

Geographic distribution.—Localities as follows:

Idaho: Filer (type), Jerome, Hubbs Butte, Bliss, Castleford, Twin Falls, Hollister, Amsterdam, Declo, Hazelton, Wendell, Burley, Tuttle, Buhl, Kimama, Hagerman (35 specimens, all from Wind Vane traps, NMC).

Remarks.—This very distinct species bridges to a certain extent the gap between the *octonotata* and the *gemma* groups. It is named in honor of Dr. E. A. Chapin, of the United States National Museum.

III. GEMMA GROUP

This is a large group with many species in Central and South America, and rather abundantly represented in the western United States. The elytral pattern consists of a marginal spot or a marginal vitta, a discal spot located in front of the middle of the length of the elytron, and an apical spot which in some species is heart-shaped. Penis and the paramera short and broad.

HYPERASPIS PRATENSIS PRATENSIS Leconte

PLATE 2, FIGURE 47

Hyperaspis pratensis LECONTE, 1880, p. 188.—CROTCH, 1873, p. 380.—SCHAEFFER, 1908, p. 126.
Hyperaspis triplicans CASEY, 1924, p. 163.
Hyperaspis triplicans microsticta CASEY, 1924, pp. 163-164.

Rounded oval, subhemispherical. In the male head and mouth parts yellow, in females respectively black and brown. Pronotum with strongly converging sides, in both sexes with large yellow spots laterally, the inner margins of which are convex inward. Elytral spots relatively small in comparison to other species of the *gemma* group, the marginal one semicircular, the discal and apical ones rounded. Pronotum densely but obsoletely punctate, elytra somewhat less densely but much more strongly, the under side densely but strongly punctate. Legs yellow, abdomen piceous on sides. Prosternal carinae moderately long, femoral lines broad, for a certain distance running parallel to the posterior margin, the outer parts becoming obsolete before reaching the sides of the segment. Penis (pl. 4, fig. 109) very short and broad, strongly asymmetrical; paramera short, spoon-shaped, densely covered with hair; basal plates well developed, rather long and broad. Female genitalia unknown.

Length of the body, 2.5-3.7 mm.; width, 2.1-2.6 mm.

Geographic distribution.—Localities as follows:

New Jersey: Atco (NMC), Hopatcong (SC).
North Carolina: Southern Pines (type of *triplicans*, CC).
Ohio: State record (NMC).
Illinois: southern part (NMC).
Missouri: State record (NMC).
Iowa: County No. 54 (SC).

Remarks.—*Triplicans* Casey is, as shown by the type, a synonym of *pratensis* Leconte. Casey's subspecies *microsticta* is represented by a single individual from the same locality as the typical form, and seems to be nothing more than a diminutive, probably underfed, specimen. The species seems to be a rare one.

HYPERASPIS PRATENSIS MEDIALIS Casey

PLATE 1, FIGURE 5

Hyperaspis medialis CASEY, 1899, p. 123.

Smaller than the typical form, slightly less strongly convex. The elytral spots relatively much larger, the marginal and apical ones broadly oval. Among the three males studied, one had a yellow anterior margin of the pronotum, in the other two this part was black, as in females. The punctulation of the elytra more dense and less deep than in the typical *pratensis.* Male genitalia (one male from Arizona studied) proved to differ from those of *pratensis* only in being smaller.

Length of the body, 2.2-2.6 mm.; width, 1.8-2.2 mm.

Geographic distribution.—Localities as follows:

Texas: Brownsville, Esperanza Ranch, Alpine, Davis Mountains.
Arizona: Williams, Cochise County, Palmerly, Santa Rita Mountains.

Remarks.—Despite the rather clear separation between the typical *pratensis* and *medialis,* I find no sufficient reason to treat them as distinct species. The identity of *medialis* with *sexverrucata* Gorham postulated by Schaeffer (Sci. Bull. Brooklyn Inst., p. 145, 1905) is more doubtful. I have seen a series of specimens of what I take to be *sexverrucata* from Granada, Nicaragua (NMC), and they appear to me to resemble *conspirans* Casey rather than *medialis.* Casey is mistaken in believing that the female of *medialis* has a pale head; his type series consists of males only.

HYPERASPIS PRATENSIS AEMULATOR Casey

PLATE 1, FIGURE 6

Hyperaspis aemulator CASEY, 1908, p. 413.

Generally intermediate in external characters between the typical *pratensis* and the subspecies *medialis.* The elytral spots rather large, the discal one rounded, the apical one transversely oval, the marginal the smallest of the three, semicircular. Genitalia unknown.

Length of the body, 2.5-2.7 mm.; width, 2.0-2.2 mm.

Geographic distribution.—Localities as follows:

Arizona: Nogales (type, CC), Huachuca Mountains (SC), Palmerly (SC), Graham Mountains (SC).
? **Iowa:** Panora (D. M. Johnson, 1 ♀, SC).

Remarks.—In my opinion, *aemulator* is simply a synonym of *pratensis.* I preserve the former name because the material available is too small to permit reaching a definitive conclusion. The single individual from Iowa resembles more the specimens I have seen from Arizona than those from the eastern United States.

HYPERASPIS CONSPIRANS Casey

PLATE 1, FIGURE 1

Hyperaspis conspirans CASEY, 1908, p. 414.

Smallest among the species of the *gemma* group in the United States, broadly oval, strongly convex. In males head and mouth parts yellow with a black stripe on the vertex which is much broader on the sides than in the middle, in females head black; pronotum in both sexes with large yellow spots laterally, the inner margin of the spots strongly arcuate, in males sometimes indications of a yellow anterior margin. Elytra with rather large spots, the marginal one elongate, at least twice longer than wide, the discal rounded, the apical one obliquely oval, at times with indications of the heart-shapedness characteristic of *gemma*. Punctulation moderately dense and rather fine. Legs pale, all femora and hind tibiae infuscate in females, only hind femora so in males, abdomen frequently piceous. Prosternal carinae reach farther forward than in *pratensis,* femoral lines semicircular. Penis (pl. 4, fig. 107) relatively narrow, the tubercle on the convex side closer to the base than to the apex. Female genitalia as in *gemma* but smaller.

Length of the body, 1.9-2.3 mm.; width, 1.5-1.8 mm.

Geographic distribution.—Localities as follows:

Texas: Brewster County, Chisos Mountains (NMC).
Arizona: Prescott, Cochise County, Palmerly, Oracle, Chiricahua Mountains, Empire Mountains, altitude 5,000 feet, Nogales (type, CC).

Remarks.—This species may prove to be a race of *sexverrucata* Gorham.

HYPERASPIS GEMMA Casey

PLATE 1, FIGURE 4

Hyperaspis gemma CASEY, 1899, p. 123; 1908, p. 414.

Broadly oval, strongly convex. In males head and mouth parts yellow with a rudimentary black stripe on the vertex, in females head black, mouth parts brown. Pronotum with large yellow spots laterally, in males in addition with a rather wide yellow anterior margin; the width of the lateral spots is, in males, equal to that of the central black area of the pronotum, the inner margin with an indentation at one-third of the length. Elytral spots large; the marginal one extending from one-fifth to three-fifths of the length, from twice to three times longer than wide, its sides subparallel; the discal spot rounded or obliquely oval; the apical one heart-shaped; the color of the spots pale yellow. Punctulation of the pronotum and the elytra moderately sparse and fine, that of the under side somewhat stronger. Legs brown in females, tibiae and tarsi lighter, yellow in males, sides of the abdomen frequently piceous. Penis (pl. 4, fig. 108) relatively long and narrow, shorter than the paramera, with an obtuse tubercle at the middle of the length of the convex side. Capsule of the spermatheca spheroidal, the proximal portion short and broad, connecting duct rather short.

Length of the body 2.2-2.8 mm.; width, 1.8-2.2 mm.

Geographic distribution.—Localities as follows:

Texas: Brownsville (type, CC), El Paso (NMC), Alpine (CASC).
New Mexico: Las Vegas, Santa Fe.
Arizona: Hot Springs, Grand Canyon, Williams, Prescott, Fort Grant, Oracle, Santa Catalina Mountains (elevation 8,500 feet).
California: San Diego (NMC), Potholes, Imperial County (E. P. Van Duzee, CASC).
Mexico: Durango, Tepehuanes (CC).

HYPERASPIS FASTIDIOSA FASTIDIOSA Casey

PLATE 1, FIGURE 2

Hyperaspis fastidiosa CASEY, 1908, p. 414.

Less broadly oval than other species of *gemma* group (except subspecies *septentrionis*), strongly convex. In males head and mouth parts yellow, a black transverse stripe on the vertex, pronotum yellow with a black quadrilobed design on the base, sometimes reduced to an uneven transverse stripe; in females head black becoming brown toward the labrum, mouth parts brown, pronotum black with large yellow spots laterally which are wider than long. Elytra with a marginal spot transformed into a marginal vitta extending from the base to beyond the middle, becoming gradually wider posteriorly; discal spot large, longitudinally oval; apical spot heart-shaped, frequently showing a tendency toward confluence with the marginal and discal spots, color of the spots from yellow to yellowish-white. Punctulation rather fine and sparse. Under side black or brownish, legs fuscous yellow in males, brown in females. Prosternal carinae moderately long, femoral lines semicircular. Penis (pl. 4, fig. 105) rather short and broad, asymmetry not clearly pronounced, obliquely cut at the distal end. Female genitalia like those of *gemma*.

Length of the body, 2.1-2.7 mm.; width, 1.6-1.9 mm.

Geographic distribution.—Localities as follows:

Colorado: Fort Garland (Th. Dobzhansky).
Arizona: Grand Canyon, Hot Springs, Peach Springs, Yuma.
Utah: Kanab, American Fork, American Fork Canyon.
Nevada: Las Vegas, Elko, Carson City, Reno.
California: Independence, Big Pine, Bishop, Olancha, Lone Pine, Kern County (on *Artemisia* sp., feeding on *Orthezia artemisiae*, F. T. Scott), Santa Paula, Los Angeles, San Diego (type, CC), Palm Springs, Potholes.
Oregon: Harvey County (SC), Umatilla, Union, Maupin, Klamath Agency.

Remarks.—This species has been described by Casey on the basis of a single specimen which is a female and not a male as thought by

Casey. The specimens from Utah and Oregon are intermediate between *fastidiosa* and *septentrionis.*

HYPERASPIS FASTIDIOSA SEPTENTRIONIS, new subspecies

PLATE 2, FIGURE 48

Slightly more oblong and less convex than the type form, punctulation of the elytra finer but denser, color of the pale markings on the pronotum and the elytra greenish-yellowish-white. Marginal vitta usually confluent with the apical spot, and the latter with the discal spot, thus the elytra being pale with a black base, a black vitta along the suture, and another black vitta at one-third of the width of the elytron extending from the base to about three-fourths of the length. Genitalia as in the typical *fastidiosa.*

Length of the body, 2.2-2.8 mm.; width, 1.5-1.9 mm.

Type and 189 paratypes.—U.S.N.M. No. 54201.

Geographic distribution.—Localities as follows:

Wyoming: Yellowstone Park (NMC), Grand Teton Park (Th. Dobzhansky).
Idaho: Murtaugh (type, NMC), Hollister, Burley, Hubbs Butte, Hansen, Tuttle, Twin Falls, Paul, Castleford, Filer, Jerome, Gooding, Wendell, Buhl, Amsterdam, Hazelton, Declo, Milner, Bliss, Shoshone, Craters of the Moon, Ashton, Melba, American Falls, Rexburg (most of the specimens from Wind Vane traps).
Arizona: Grand Canyon (SC).

IV. LATERALIS GROUP

Here belongs the common species *lateralis* Mulsant which is greatly differentiated geographically, and several less widespread forms; as far as the writer is aware, this group is not abundant in the Tropics. The elytral pattern consists of a marginal vitta, a discal spot lying in front of the middle of the length of the elytron, and an apical spot. Penis short and broad, strongly asymmetrical, paramera much dilated, spoon-shaped.

HYPERASPIS LATERALIS LATERALIS Mulsant

PLATE 2, FIGURE 39

Hyperaspis lateralis MULSANT, 1850, p. 657.—LECONTE, 1880, p. 187.—CASEY, 1899, p. 122.
Hyperaspis laevipennis CASEY, 1899, p. 122.—BOWDITCH, 1902, p. 207.
Hyperaspis pinguis CASEY, 1899, p. 122.—BOWDITCH, 1902, p. 207.

Very broadly oval, strongly convex. In males head and mouth parts yellow, pronotum with the lateral and anterior margins narrowly yellow; in females head black, pronotum black with or without reddish spots in the anterior angles. Elytral markings blood red or orange; marginal vitta extending from the base to two-fifths of the length of the margin, broad, parallel-sided, not produced inward along the base, although in some individuals decidedly broader anteriorly; discal spot round or slightly longitudinally oval; apical spot round or transversely oval. Punctulation dense but fine. Epimera of the mesosternum white in males, black in females; front legs, tibiae and tarsi of middle and hind legs brownish yellow in males, in females only tarsi brownish. Prosternal carinae fused not far from the anterior margin; femoral lines broadly arcuate, merely touching the hind margin of the first abdominal sternite, their external parts not reaching the sides of the segment. Sides and tip of the abdomen occasionally piceous. Penis (pl. 4, fig. 120) much shorter than the paramera, the latter very broad, their edges covered with dense and long hair. Capsule of the spermatheca retort-shaped (pl. 6, fig. 162), gradually passing into the connecting duct, basal portion with a short appendix.

Length of the body, 2.6-3.8 mm.; width, 2.3-3.0 mm.

Geographic distribution.—Localities as follows:

Colorado: Durango (Th. Dobzhansky).

Texas: Green Valley, El Paso.

New Mexico: Las Vegas, Fort Wingate, Las Cruces, Mesilla Park.

Arizona: Chiricahua Mountains, Rustler Park, Pima County, Apache Lake, Globe, Santa Catalina Mountains, Tucson, Nogales.

Nevada: Dixie, Elko.

California: San Francisco, Alameda, Oakland, Fairfax, Paraiso Springs, Redwood City, Sacramento, Fresno (on *Pseudococcus citri*), Sequoia Park, Mineral King, Monterey County, Carmel, San Luis Obispo County, Santa Barbara, Santa Paula, Ventura, Inglewood, Los Angeles, Pasadena, Soledad Canyon, Duarte, Pomona, San Bernardino, Riverside, between Big Pines and Palmdale, Independence, Bishop, Chino, Whittier, Elsinore, San Diego, Warners Springs, Pine Valley, Jacumba, Blythe, Needles. Common along California coast, especially on scale-infested Monterey cypress and *Araucaria.*

Mexico: Sonora (P. H. Timberlake collection), Aguascalientes (NMC).

HYPERASPIS LATERALIS MONTANICA Casey

Plate 2, Figure 40

Hyperaspis montanica Casey, 1899, p. 121.

Less broadly oval than the typical form, strongly convex; the yellow margins on the pronotum in males narrower, the elytral markings yellow instead of red, the discal and apical spots small, the marginal vitta narrow and produced along the base of the elytron for a distance about equal to twice its width. Genitalia identical.

Length of the body, 2.6-3.2 mm.; width, 2.0-2.5 mm.

Geographic distribution.—Localities as follows:

British Columbia: Pavilion (Th. Dobzhansky), Vernon, Skaha.
Montana: Helena (type, CC), Broadwater County (University of Minnesota collection).
South Dakota: Hill City (Th. Dobzhansky).
Wyoming: Yellowstone Park, Grand Teton Park, Worland, Gillette, Ucross.
Idaho: Jerome, Hubbs Butte, Burley, Wendell, Murtaugh, Paul, Buhl, Kimberly, Hollister, Gooding, Castleford, Tuttle, Declo, Amsterdam, Bliss, Wickahoney, Boise, Parma, Twin Falls, Cow Creek, Beaver Canyon, Pocatello, Craters of the Moon.
Washington: Toppenish, Wallula Gap, Yakima, Coulee City, Ewan, Lake Chelan.
Oregon: Riddle, Hermiston, North Powder, Ontario, Harvey County, Baker, Lake County, Summer Lake, Lakeview, Bend, Steen Mountains, Klamath Falls.
Colorado: Canon City, Dixon, Estes Park, Fort Collins, Manitou.
Nevada: Steamboat Springs (Van Dyke, CASC).
California: Lava Beds National Monument; Coleville, Mono County (SC).

HYPERASPIS LATERALIS FLAMMULA Nunenmacher

PLATE 2, FIGURE 41

Hyperaspis lateralis var. *flammula* NUNENMACHER, 1911, p. 72.

Shape of the body as in subspecies *montanica;* elytral marking usually bright orange, but varying from yellow to bright red; the marginal vitta prolonged past the middle of the length of the elytron, greatly expanded and fused with a much enlarged discal spot; apical spot transversely oval. In some specimens the marginal vitta is fused also with the apical spot; at the humeral angles the vitta may or may not be produced along the base (as in *montanica*). Genitalia identical with those of the type form.

Geographic distribution.—Localities as follows:

Montana: State record (23 specimens, NMC).
Alberta: Medicine Hat (SC).
Wyoming: Ucross, Gillette, Worland, Sundance.
Colorado: Golden, Canon City, Manitou.

HYPERASPIS LATERALIS NIGROCAUDA, new subspecies

PLATE 2, FIGURE 42

Differs from the typical *lateralis* by having the apical spot obsolete; the marginal vitta broad, parallel-sided, the discal spot large, rounded or subtriangular; elytral markings blood red. Punctulation of the elytra very fine. Genitalia unknown.

Type and eight paratypes.—U.S.N.M. No. 54202.

Geographic distribution.—Localities as follows:

Colorado: Canon City (5 specimens, including the type, NMC), Paonia (E. C. Van Dyke, CASC).
Utah: Bryce Canyon (SC).
New Mexico: Las Vegas Hot Springs (NMC).
Arizona: Grand Canyon (reared from larvae collected from hawthorn, where they were feeding apparently on aphids, SC).
Nevada: Carson City, Dixie (SC).
California: San Francisco (1 individual, SC).

HYPERASPIS LATERALIS OMISSA Casey

PLATE 2, FIGURE 43

Hyperaspis lateralis var. *omissa* CASEY, 1899, p. 122.

Oval, somewhat less convex than other races of *lateralis,* elytra very finely punctulate, shining. Elytral marking blood red, the discal spot obsolete, the marginal vitta either as in the typical *lateralis* or as in *montanica,* the apical spot large, usually extended along the outer margin, the anterior boundary of the spot usually straight. Genitalia identical with those of the typical *lateralis.*

Length of the body, 2.8-3.2 mm.; width, 2.1-2.4 mm.

Geographic distribution.—Localities as follows:

New Mexico: Las Vegas Hot Springs (36 specimens, NMC), Santa Fe (CASC).
Arizona: Grand Canyon (type, CC), Bright Angel (1 specimen, NMC).
Utah: Salt Lake City (NMC), Crane Valley (SC).
Nevada: Dixie (1 specimen, SC).
California: Placer County (3 specimens, P. H. Timberlake collection).

HYPERASPIS LATERALIS WELLMANI Nunenmacher

PLATE 2, FIGURE 44

Hyperaspis wellmani NUNENMACHER, 1911, p. 72.

Body size and shape intermediate between *lateralis lateralis* and *lateralis montanica;* elytral markings yellow or orange, marginal vitta narrow at humeral angles, not produced along the basal margin, distinctly increasing in width posteriorly; the discal and apical spots small, rounded; genitalia identical with those of the typical form.

Geographic distribution.—Localities as follows:

Washington: Yakima (5 specimens, NMC), Toppenish (2 specimens, SC).
Idaho: Craters of the Moon (1 specimen, SC).
Utah: American Fork (1 specimen, NMC).
Nevada: Goldfield (2 cotypes in C. W. Leng and H. L. MacKenzie collections).
California: State record (NMC).

Remarks.—In his description of *wellmani* Nunenmacher states that the larvae of this form are "strikingly different" from those of *lateralis* but omits to describe the nature of the difference. According to the original description, *wellmani* should have deeper foveae for the reception of the hind tibiae than *lateralis,* but I am unable to see this difference either in the two cotypes which I have examined or in other specimens that otherwise fit Nunenmacher's description.

HYPERASPIS LATERALIS IDAE Nunenmacher

Hyperaspis idae NUNENMACHER, 1912, p. 450.

Differs from the typical *lateralis* in having the marginal vitta reduced to a semicircular spot located at about one-third of the external margin of the elytron. Genitalia identical with those of the typical form.

Geographic distribution.—Localities as follows:

California: Guerneville (cotype, C. W. Leng collection), Klamath Glen (3 individuals, Th. Dobzhansky), San Francisco (1 specimen, SC), Redwood City (14 specimens, SC), Lagunitas (E. C. Van Dyke, CASC).

Remarks.—*Hyperaspis lateralis* shows a great individual as well as geographic variability both in the structural characters and in the color pattern. This variability is very instructive and would repay a closer study. Certain individual variants were described as separate species (*laevipennis* Casey, *pinguis* Casey), the invalidity of which is easily demonstrable if larger series are studied. Geographically, the different characters vary to a certain extent independently; for example, individuals which are structurally *montanica* may have either *montanica* or *flammula* color patterns. The color patterns may be subdivided into several discrete types the intermediates between which are sufficiently infrequent to permit a clear separation; these types of patterns are used above as chief characteristics of the several subspecies. Since apparently only a few genes, or gene alleles, are involved in the production of the types of patterns, the latter may coexist in the same population. Thus, both *montanica* and *flammula* are recorded for several localities in Wyoming, the preceding two as well as *nigrocauda* at Canon City, Colo., *montanica* and *wellmani* at Yakima, Toppenish, and Craters of the Moon. A series of 155 specimens collected at Redwood City, Calif., by F. T. Scott contained 14 specimens of *idae,* 132 of typical *lateralis* and 9 intermediates. However, it must be emphasized that the relative frequencies of various color patterns are unlike in different geographic regions; among almost 2,000 individuals from southern California nothing but *lateralis* was found. Moreover, the subspecies are characterized not only by color patterns but by structural differences as well; the latter appear to be genetically more complex and, hence, geographically more stable. The advantage of using color patterns for characterizing subspecies is obvious, namely, simplicity of classification. The use of the structural differences would involve an extensive statistical work, but the results obtained would be, in a sense, more reliable.

HYPERASPIS EXCELSA Fall

PLATE 2, FIGURE 45

Hyperaspis excelsa FALL, 1901, p. 232.

Large, broadly oval, strongly convex. In males head and mouth parts yellow, pronotum with yellow lateral and anterior margins, the former being broader than the latter; in females head and pronotum black, mouth parts brown. Elytra with a blood-red marginal vitta extending from the humeral angle to about three-fifths of the length, deflected from the margin in its posterior part and broadly confluent with the enlarged discal spot; a small transversely oval apical spot may or may not be present. The upper surface polished, shining, pronotum minutely and rather sparsely punctulate, elytra still more sparsely and very delicately so, punctulation of the under side rather dense and moderately strong. Coloration of the under side, prosternal carinae, and femoral lines as in *lateralis*. Genitalia differ from those of *lateralis* chiefly in size, but penis seems to have a more pronounced tubercle on the convex side (pl. 4, fig. 114).

Length of the body, 3.6-4.2 mm.; width, 2.9-3.4 mm.

Geographic distribution.—Localities as follows:

California: Pomona (cotype, NMC), San Bernardino County, Los Angeles (feeding on *Pseudococcus yuccae*, NMC, SC), Pasadena (CASC), total of 8 individuals examined.

Remarks.—A close relationship as well as a specific distinctness of *excelsa* and *lateralis* are beyond doubt.

HYPERASPIS TAEDATA Leconte

PLATE 2, FIGURE 46

Hyperaspis taedata LECONTE, 1880, p. 187.

Body shape as in *lateralis* and *excelsa* but size much smaller. Head yellow with a transverse bilobed black stripe on the vertex (male?), or, in addition, with a black epistoma (female?), pronotum with triangular yellow spots in anterior angles (female?) or with a rather broad yellow stripe on the lateral margin (male?). The color pattern of the elytra as in *excelsa*. Punctulation of the pronotum dense but rather fine, that of the elytra much stronger, that of the under side dense and medium strong. Pronotal carinae and femoral lines as in *lateralis,* coloration of the under side piceous, mesosternal epimerae in the male apparently dark. Genitalia unknown.

Length of the body, 2.4 mm.; width, 1.8 mm.

Geographic distribution.—Localities as follows:

Florida: State record (C. W. Leng collection), Enterprise (NMC).

Remarks.—Although this species is altogether insufficiently known, there is little doubt that it is separate from *excelsa* which it most closely resembles.

HYPERASPIS LUGUBRIS (Randall)

PLATE 2, FIGURE 70

Coccinella lugubris RANDALL, 1838, p. 52.—MULSANT, 1850, p. 1051.—LECONTE, 1880, p. 188.—CASEY, 1899, p. 128.
Hyperaspis jucunda LECONTE, 1852, p. 134.
Hyperaspis lecontei CROTCH, 1874, p. 233.
Hyperaspis venustula MULSANT, 1850, p. 671.
Hyperaspis separata CASEY, 1924, p. 165.

Elongate oval, little convex, broadly rounded behind, sides of the elytra rather feebly arcuate in their middle part. In males head and the pronotum ochreous yellow, the latter darker at the base in front of the scutellum; in females head yellow, pronotum with yellow lateral margins, the anterior margin in some individuals also narrowly yellow, the width of the yellow stripes variable and their internal boundaries indistinct. Elytra with a yellow or ochreous-yellow marginal vitta extending from the base to two-thirds of the length, expanded posteriorly in the part corresponding to the marginal spot and constricted immediately in front of the expansion, a longitudinally oval discal spot equidistant from the suture and from the margin, located definitely in front of the middle of the length, and a rounded or longitudinally oval apical spot lying somewhat closer to the suture than to the external margin at four-fifths of the length of the elytron. Pronotum and the elytra alutaceous, the former densely but very minutely punctulate, the latter less densely but more strongly so, punctulation of the under side very dense but fine, except on the sides of the mesosternum, where it is dense and strong. Under side brownish yellow, mesosternum and metasternum and the base of the abdomen darker, brown or black. Prosternal carinae low but reaching far forward, femoral lines almost reaching the posterior margin, running for a distance parallel to the latter, becoming angular externally, and disappearing without attaining the sides of the segment. Penis and paramera very short and broad, the former distinctly shorter than the latter (pl. 6, fig. 152), strongly asymmetrical; basal plates powerfully developed. Female genitalia unknown.

Length of the body, 2.4-3.3 mm.; width, 1.6-2.4 mm.

Geographic distribution.—Localities as follows:

Massachusetts: State record (SC).
New York: West Point (W. Robinson, 1 ♀, NMC), Pinelawn (Schaeffer, SC).
New Jersey: Greenwood (C. W. Leng collection).
Kansas: Topeka, Riley County (NMC).
Iowa: Iowa City (C. W. Leng collection).
Colorado: State record (NMC).
Texas: State record (NMC).

Remarks.—*Hyperaspis lugubris* has no close relatives in the fauna of the United States. It is placed in the *lateralis* group only on the basis of a similarity of the male genitalia, which may prove to be accidental. It may be noted that the head and pronotal coloration in females of *lugubris* resembles that encountered in males of many other species of *Hyperaspis*.

V. PROBA GROUP

Body rounded oval, strongly convex, almost hemispherical. The elytral pattern consists of a marginal vitta, a discal spot, and two apical spots lying at the same level and forming a row of four spots across the apical parts of the two elytra; they may be termed the inner and the outer apicals. Penis short and broad, paramera tapering toward the end, the end covered with a small tuft of short bristles—a condition found in no other group of species of *Hyperaspis* in the United States.

HYPERASPIS PROBA PROBA (Say)

PLATE 1, FIGURE 35

Coccinella proba SAY, 1826, p. 303.—MULSANT, 1850, p. 674.—LECONTE, 1880, p. 188.—CASEY, 1899, p. 122.

In the male head yellow or yellowish white, pronotum with yellow subquadrate spots on the lateral margins, and with a narrow vitta of the same color on the anterior margin, antennae, front legs, knees, tibiae and tarsi of middle and hind legs brownish yellow; in the females head black, pronotum yellow laterally, the yellow part being longer than wide, coloration of the under side like that in the males. The elytral spots yellow or yellowish white, seldom orange red; the discal spot round or slightly transversely oval, lying a little closer to the external margin than to the suture; the marginal vitta wanting; the two apical spots rounded, much smaller than the discal one, and occasionally reduced to a point, or even disappearing altogether. Head, pronotum and the elytra densely and finely punctulate, the elytral punctures somewhat stronger than the pronotal ones, punctulation of the under side very dense and rather coarse. Prosternal carinae forming a very sharp angle, and reaching up to a point not far from the anterior margin; femoral lines flatly arcuate, not reaching the posterior margin, externally disappearing before attaining the sides of the first abdominal sternite. Penis (pl. 5, fig. 145) shorter than the paramera, very broad at base; basal plates with a toothlike process. Basal portion of the spermatheca (pl. 6, fig. 163) provided with a very large strongly chitinized appendix, the size of which exceeds that of the basal portion proper; the capsule rounded, suddenly giving rise to the connecting duct.

Length of the body, 2.1-3.0 mm.; width, 1.7-2.5 mm.

Geographic distribution.—Found generally over eastern United States from Massachusetts to Florida and westward to Minnesota, South Dakota, Nebraska, Kansas, Arizona, New Mexico, and Texas. A specimen has been seen labeled as from Fresno, Calif. (NMC).

Remarks.—A small individual from New Mexico has been described by Casey (1899, p. 123), as variety *trinifer;* this variety is supposed also to have the apical spots of the same size as the discal one. The final disposition of this name must await further data. The finding of *proba* in California is somewhat doubtful.

HYPERASPIS PROBA WEISEI Schaeffer

PLATE 1, FIGURE 17

Hyperaspis weisei SCHAEFFER, 1908, p. 126.

Differs from the typical form in being somewhat more strongly convex, in having a finer punctulation of the elytra, and in possessing a marginal spot or a marginal vitta. The elytral spots larger than in the typical form, the outer apical one almost reaching the external margin; the marginal spot either semicircular or produced cephalad to form a marginal vitta which is much broader posteriorly than anteriorly. Genitalia unknown.

Length of the body, 2.6-2.7 mm.; width, 2.3 mm.

Geographic distribution.—Localities as follows:

Texas: Brownsville (Schaeffer, cotype, SC), Davis Mountains, (J. N. Knull, SC).

Remarks.—In view of the scarcity of the available material, my treatment of *weisei* as a subspecies of *proba* is admittedly hazardous. The two forms are, however, so similar externally that intermediates between them are to be expected; the specimens of *proba* from the southern part of its distribution have a finer punctulation than the northern ones, thus being, to a degree, intermediate between the northern *proba* on one hand and *weisei* on the other.

HYPERASPIS GLOBULA Casey

Plate 2, Figure 49

Hyperaspis globula Casey, 1899, p. 124.

Small, rounded, oval, subhemispherical. Head yellowish white in males, black in females; pronotum with pale yellow subquadrate spots laterally, in males, in addition, with a pale anterior margin. Elytra with a large, rounded, yellowish-white discal spot located slightly closer to the suture than to the external margin, and behind the middle of the length. Punctulation of the pronotum dense and strong, that of the elytra stronger still, that of the under side moderately strong, except that on the metasternum the punctures are very large and shallow. Mouth parts, front legs, tibiae and tarsi of the middle and hind legs, and, in some of the males but not in others, mesosternal epimerae pale. Prosternal carinae very long, practically attaining the anterior margin; femoral lines very flat, their external part forming a sharp angle with the posterior border, not attaining either the posterior or the side margins. Male genitalia (pl. 5, fig. 150) of the same type as in *proba* but much smaller, penis almost as long as the paramera, basal plates without teeth. Spermatheca (pl. 6, fig. 164) with a rudimentary capsule and a large appendix on the basal portion, which, however, does not attain the degree of hypertrophy it does in *proba*.

Length of the body, 1.8-2.0 mm.; width, 1.4-1.6 mm.

Geographic distribution.—Localities as follows:

Texas: Brownsville, Esperanza Ranch, Hidalgo County (NMC, SC).
Mexico: Tampico (NMC).

Remarks.—This small species is very interesting since it constitutes a bridge between the *proba, connectens,* and *binotata* groups of species which otherwise would be quite isolated. At the same time *globula* is obviously a highly specialized form (reduction of the capsule of the spermatheca), which in any case prevents its consideration as an ancestor of the other groups of forms.

VI. CONNECTENS GROUP

The fauna of the United States has only two species of this group, both of which occur only in the extreme South, close to the Mexican border. The elytral pattern consists of large discal and apical spots which may or may not be confluent with each other. Male genitalia are characterized by small basal plates and broad paramera the basal portions of which are overdeveloped at the expense of the basal plates. The capsule of the spermatheca spherical rather than retort-shaped.

HYPERASPIS CONNECTENS (Thunberg)

PLATE 2, FIGURE 67

Coccinella connectens THUNBERG, in Schönherr, 1808, p. 157.—MULSANT, 1850, p. 662.

Hyperaspis lengi SCHAEFFER, 1905, p. 144; 1908, p. 126.

Broadly oval, moderately convex. Head and mouth parts yellow in males, black in females. Pronotum in both sexes broadly yellow laterally, the internal boundaries of the yellow areas more or less straight, the anterior margin of the pronotum yellow in males. The elytral spots yellow, the discal one rounded or transverse, the apical one large, attaining the external margin but not the suture, its inner outline concave, usually broadly confluent with the discal spot. Head and the pronotum densely but finely punctulate, interstices barely perceptibly alutaceous, punctulation of the elytra moderately sparse and strong, that of the under side rather sparse and fine. Tibiae and tarsi yellow, sides of the abdominal sternites brown. Prosternal carinae short, femoral lines strongly arcuate, not attaining the posterior margin, their outer parts forming a sharp angle with the sides of the segments, usually reaching or almost reaching the anterior angles. Penis (pl. 4, fig. 116) shorter than the paramera, strongly asymmetrical, its base rather narrow, strongly expanded at the middle, and acuminate at the tip. The basal parts of the large spoon-shaped paramera densely covered with large pores; the basal plates very short. The capsule of the spermatheca almost spherical, the connecting duct long, basal portion elongate, provided with a short appendix.

Length of the body, 2.5-3.0 mm.; width, 2.0-2.3 mm.

Geographic distribution.—Localities as follows:

Texas: Brownsville, Esperanza Ranch, San Benito, Harlingen, Hidalgo County, Edinburg, Mission.

Arizona: Pima County, Phoenix, Palmerly, Tucson, Nogales, Huachuca Mountains.

Mexico: Orizaba (NMC).

Guatemala: Huehuetenango (Th. Dobzhansky), Guatemala City (Champion, NMC).
Honduras: State record (F. J. Dyer, NMC).
Nicaragua: San Marcos, Chinandega (NMC).
Jamaica: Kingston (NMC).
Haiti: Hinche, Boucan (H. L. Dozier, NMC).
Santo Domingo: Santo Domingo, Halpa (on cotton, U. C. Leftin, NMC).
Puerto Rico: Bayamon (A. Busck, NMC).

Remarks.—I see no difference between *lengi* Schaeffer and *connectens* (Thunberg), except that the frequency of the confluence of the discal and apical spots is greater in the populations from Texas than in those from Arizona or Central America. Genitalia of a few specimens from Nicaragua proved to be identical with those of Texas specimens.

HYPERASPIS ROTUNDA Casey

PLATE 2, FIGURE 66

Hyperaspis rotunda CASEY, 1899, p. 123.
Hyperaspis rotundata (Casey) KORSCHEFSKY, 1931, p. 195.

Broadly oval, somewhat obtusely rounded behind, strongly convex. Coloration of the head and the pronotum as in *connectens,* except that the yellow spots on the lateral portions of the pronotum larger and tending to become wider posteriorly, so that the central black area appears constricted at base. Elytra with a large, pale yellow, longitudinally oval discal spot, and an apical spot of the same color extending from about the middle to the apical eighth of the external margin and attached to the latter; confluence of these spots has never been observed, the anterior margin of the apical one convex. Punctulation of the pronotum as in *connectens,* that of the elytra much sparser and rather fine, that of the under side stronger. Legs yellow, epimera and episterna of the mesonotum as well as the abdomen fuscous. Prosternal carinae strong, almost reaching the anterior margin; femoral lines much less strongly arcuate than in *connectens,* their outer parts forming sharp angles with the posterior margin, and not reaching the sides of the segment. Penis (pl. 4, fig. 113) shorter than the paramera, more or less uniformly broad, obtusely truncate distally; paramera spoon-shaped, basal plates more strongly developed than in *connectens.* The capsule of the spermatheca (pl. 6, fig. 166) more retort-shaped than in *connectens,* basal portion elongate and narrow.

Length of the body, 2.2-2.7 mm.; width, 1.8-2.0 mm.

Geographic distribution.—Localities as follows:

Texas: Brownsville, San Tomas.
Arizona: Phoenix, Sacaton, Tucson.

VI. BINOTATA GROUP

This group attains its greatest development in the Temperate Zone of North America, although a number of its species seem to be perfectly at home in the American Tropics. Moreover, the Old World species of *Hyperaspis* (including the type of the genus, *H. reppensis* Herbst), or at least a majority of them, belong here. The elytral pattern consists of a discal, or an apical, spot, or both; however, in some species the position of the spot is such as to make the homology with the spots of the basic pattern of the genus difficult—this is the only group where such a difficulty is encountered. Genitalia rather diversified: in some species penis is short and broad, and paramera broad and spoon-shaped, in others penis is long and narrow, paramera being slender and fingerlike. Intermediate conditions also occur, making it impossible to split the groups into more uniform subdivisions.

HYPERASPIS BINOTATA (Say)

PLATE 3, FIGURE 73

Coccinella binotata SAY,' 1826, p. 302.—CROTCH, 1873, p. 380.—CASEY, 1899, p. 124.—MULSANT, 1850, p. 683 (partim).
Coccinella normata SAY, 1826, p. 302.
Coccinella affinis RANDALL, 1838, p. 50.—MULSANT, 1850, p. 1051.
Hyperaspis leucopsis MELSHEIMER, 1847, p. 179.—CROTCH, 1873, p. 380.
Hyperaspis conviva CASEY, 1924, p. 163.
Hyperaspis insolens CASEY, 1924, p. 164.

Broadly oval, strongly convex. In females head and pronotum black, in males head yellow with a black bisinuate stripe on the vertex frequently concealed by the margin of the pronotum, pronotum narrowly yellow on the lateral and the anterior margins. Elytra with a red or orange-red discal spot lying somewhat in front of the middle of the length, rounded or slightly transverse. Punctulation of the pronotum dense and moderately strong, interstices feebly or not at all alutaceous, that of the elytra as dense but stronger, that of the under side dense and strong. Under side black, front legs dark piceous in females, yellow in males. Prosternal carinae forming a very sharp angle, reaching far forward, femoral lines strongly arcuate, their middle parts running subparallel to the posterior margin of the segment, their outer parts angular. Penis (pl. 4, fig. 123) only slightly shorter than the paramera, long and narrow, knife-shaped, with straight sides, the end bluntly cut off; paramera long, fingerlike; basal plates moderately developed. Capsule of the spermatheca (pl. 6, fig. 165) nearly spherical, the basal portion large, with a small appendix.

Length of the body, 2.5-4.0 mm.; width, 2.0-3.3 mm.

Geographic distribution.—Found generally over eastern North America from Quebec to Florida and westward to Nebraska, Colorado, and Texas. The species reappears in California at Bishop (CASC).

Remarks.—This is probably the commonest species of *Hyperaspis* in the eastern United States. Casey's species *conviva* and *insolens* represent, as shown by examination of the types, merely individual variants of *binotata,* and should be treated as synonyms.

HYPERASPIS SIGNATA (Olivier)

Plate 3, Figure 78

Coccinella signata Olivier, 1808, p. 1047.—Mulsant, 1850, p. 683.—Leconte, 1880, p. 187.—Casey, 1899, p. 122.

Externally resembles *binotata* Say. Body somewhat less broadly oval, more ovoidal in shape, sides of the elytra less arcuate in their middle part, the yellow anterior margin on the pronotum sometimes obsolete at the middle. Elytra each with two red spots: a discal one situated as in *binotata,* and an apical one which is much smaller than the discal, rounded or transversely oval, in some specimens reduced in size or obsolete. Penis (pl. 4, fig. 118) much shorter than the paramera, very broad, strongly asymmetrical, dilated distally, the end sharply cut off; paramera broad. Female genitalia as in *binotata.*

Length of the body, 2.7-3.7 mm.; width, 2.1-2.9 mm.

Geographic distribution.—Occurs from New York to Florida and westward to Arkansas and Texas.

Remarks.—*H. signata* and *binotata* were considered by most authors, including even Casey, to constitute a single species. On the basis of external characters their separation is indeed difficult, owing to a great range of variability exhibited by both of them. Nevertheless, examination of large series of specimens shows that two distinct modal points are represented in the population, and that the distribution of *signata* is on the whole more southerly than that of *binotata.* All doubt about the existence of a specific difference between them is removed by investigation of the male genitalia, where the structural difference is unexpectedly striking.

HYPERASPIS PINORUM Casey

Plate 3, Figure 79

Hyperaspis pinorum Casey, 1924, p. 162.
? *Hyperaspis inedita* Mulsant, 1850, p. 684.—Crotch, 1873, p. 380.—Casey, 1899, p. 124.

Broadly oval, moderately convex. In males head yellow, pronotum with subquadrate orange-yellow spots laterally and with a yellow anterior margin, in females head black, pronotum with pale lateral spots as in the male but with the anterior margin black. Elytra with an orange or red discal spot, the spot rounded or obliquely oval, its center lying clearly caudad from the middle of the length of the elytron. Punctulation of the upper surface dense but rather fine, interstices feebly alutaceous, that of the underside very dense and strong. In males legs yellow, epimera of the mesosternum white, the abdomen piceous; in females the tibiae, tarsi, and tips of femora brownish yellow, abdomen black or with piceous spots on the sides of the abdominal sternites. Genitalia unknown.

Length of the body, 2.9-3.0 mm.; width, 2.1-2.3 mm.

Geographic distribution.—Localities as follows:

Delaware: Bethany Beach (L. J. Bottimer, SC).
North Carolina: Southern Pines (type and paratypes, CC).
Georgia: Barnesville (NMC), Milner, Clayton.
Florida: Tallahassee, Quincy, Navarre, Gainesville, Fort Walton, Lake City.
Alabama: Magazine Point (H. P. Löding, SC).

Remarks.—Casey (loc. cit.) describes this species as "convex, polished," which I do not find to be the case either in the type or in other specimens that I have examined. The identification of *inedita* with *pinorum* is uncertain since I have not seen the type of the former; the patria of *inedita* is given as North America. If their identity is confirmed, the species will, of course, have to change its name to *inedita* Mulsant.

HYPERASPIS HAEMATOSTICTA Fall

PLATE 3, FIGURE 77

Hyperaspis haematosticta FALL, 1907, p. 222.

Oval, moderately convex, sides of the elytra feebly arcuate, broadly rounded behind. In males head yellow, with or without a black stripe on the vertex, mouth parts brown, pronotum with a rather narrow yellow stripe on the anterior margin and with a two to four times broader one laterally; in females head and mouth parts black, pronotum either solid black or with a narrow yellow stripe laterally which varies in extent from a comma-shaped streak in the anterior angles to a fully developed stripe reaching the humeral angles. Elytra each with two blood-red spots: the discal one located just in front of the center of the disk and slightly closer to the suture than to the external margin, usually oblique but sometimes rounded, and a transversely oblique apical spot, which is wanting in some specimens. Punctulation of the upper surface dense but rather fine, that of the under side finer than in related species. Under side black in females with dark piceous tibiae and tarsi, in males legs brownish yellow except for the dark hind femora, epimera of the mesosternum light brown, sides of the abdomen in both sexes brown. Prosternal carinae short. Penis (pl. 4, fig. 124) knife-shaped, resembling that of *binotata* but broader, paramera almost as long as the penis. The capsule of the spermatheca retort-shaped.

Length of the body, 2.8-3.6 mm.; width, 2.0-2.6 mm.

Geographic distribution.—Localities as follows:

New Mexico: Las Vegas (38 specimens, NMC).
Arizona: Chiricahua Mountains (SC), Williams (NMC).

HYPERASPIS LEWISI Crotch

PLATE 3, FIGURE 76

Hyperaspis lewisi CROTCH, 1873, p. 380.—LECONTE, 1880, p. 187.
Hyperaspis maneei CASEY, 1924, p. 163.

Oval, compressed from the sides, lateral margins of the elytra nearly straight in their middle parts, truncate behind, pronotum only slightly narrowed anteriorly, the anterior margin feebly arcuate, the angles turned downward. In males the head, lateral margins of the pronotum broadly and the anterior margin narrowly yellow, in females head and pronotum black, the latter fuscous laterally in some individuals. Elytra with a large yellow or orange discal spot extending from the basal fourth or fifth to behind the middle of the length, and from the inner third of the width to the lateral margin which is narrowly black. Punctulation of the pronotum dense but very fine, that of the elytra almost as dense and only slightly stronger, that of the under side not dense and very fine, the middle of the metasternum and of the first abdominal sternite virtually impunctate, polished, the space enclosed by the femoral lines with a few rather coarse punctures. In females tibiae and tarsi brown, in males legs yellow or yellowish brown. Prosternal carinae exceptionally short, converging but not fused anteriorly, the anterior part of the prosternum without trace of a carina; femoral lines semicircular or slightly flattened in the part where they approach the posterior margin. Genitalia unknown.

Length of the body, 3.0-3.8 mm.; width, 2.1-2.5 mm.

Geographic distribution.—Localities as follows:

New York: West Point (W. Robinson, NMC), Bear Mountain (F. M. Schott, SC).
Maryland: Great Falls (L. L. Buchanan, NMC).
North Carolina: Southern Pines (Manee, type and paratypes, CC, NMC).
Kentucky: Louisville (H. Soltau, NMC, SC).

Remarks.—This is a very distinctive species which is only provisionally placed in the *binotata* group. It has no known close relatives.

HYPERASPIS LEACHI Nunenmacher

Plate 1, Figure 32

Hyperaspis leachi Nunenmacher, 1934, p. 19.

Broadly oval, moderately convex, sides of the elytra feebly arcuate, broadly rounded behind, head and pronotum relatively short and broad, the latter only slightly narrower anteriorly than posteriorly. In the male head yellow, pronotum with a narrow yellow stripe on the anterior margin (the margin itself remaining black) and a wider stripe on the lateral margin which is produced inward for a short distance along the base; in the female head and pronotum black, the latter with a yellow stripe laterally which is more than twice as long as wide. Elytra with a large orange-colored area extending from the basal fourth or fifth to the apical fourth or fifth of the length, and from the external margin which is narrowly black to one-fourth of the width from the suture; the outline of the orange area uneven, especially in the callus area where a black spur projects into it. Punctulation of the head and the pronotum dense but fine, that of the elytra almost as dense but still finer, that of the under side somewhat coarser. In the female the tibiae, tarsi, and the front legs yellowish brown, in the male legs yellow, posterior femora fuscous. Prosternal carinae as short as in *lewisi* but clearly fused at their anterior ends, femoral lines rather flat, their outer parts forming sharp angles with the posterior margin, with which their middle parts are subparallel. Genitalia unknown.

Length of the body, 2.5-2.8 mm.; width, 2.1-2.4 mm.

Geographic distribution.—Localities as follows:

California: San Diego County (1 ♂, F. T. Scott, SC), Kern County (1 ♀, F. T. Scott, SC).

Remarks.—Nunenmacher correctly believes this species to be related to the Mexican *panzosae* Gorham, and in fact it may be only a race of the latter. I have seen *panzosae* from Mexico City (NMC), but my notes on it are unfortunately inadequate. The following two species appear to be also rather closely related. The two individuals of *leachi* which I have examined are larger than the dimensions given by Nunenmacher indicate, namely 2.20 mm. in length and 1.75 in width.

HYPERASPIS REGALIS Casey

Hyperaspis regalis Casey, 1899, p. 123.

Broadly oval, rather strongly convex. In the type, which is apparently a female, pronotum with subquadrate, internally rounded yellow spots on the lateral margin. Elytra with a large orange spot extending from the basal fourth to the apical fifth of the length and from the inner to the outer fourth of the width of the elytron. Punctulation dense but very fine. Legs black, except for the light brown anterior tibiae and tarsi. Genitalia unknown.

Length of the body, 3.0 mm.; width, 2.2 mm.

Geographic distribution.—Locality as follows:

Florida: Jacksonville (type, CC).

HYPERASPIS NIGROSUTURALIS Blatchley

Hyperaspis nigrosuturalis Blatchley, 1918, p. 420.

Very broadly oval, strongly convex. In the female head and pronotum black. Elytra orange red with a black sinuate fascia basally reaching to one-sixth of the length, and black stripes on the suture and on the external margin, the sutural stripe being twice as wide as the marginal one, and both becoming wider posteriorly. Punctulation of the head and the pronotum dense and moderately strong, that of the elytra almost as dense but not quite as strong as that of the pronotum, that of the under side dense and medium strong. Legs black, front tarsi piceous. Prosternal carinae very short, femoral lines broad, their middle parts running parallel to the posterior margin. Genitalia unknown.

Length of the body, 3.1 mm.; width, 2.5 mm.

Geographic distribution.—Locality as follows:

Florida: Lake Alfred (1 ♀, R. Miller, NMC).

Remarks.—This species is very close to, and in fact may represent only an indistinct race of, the Mexican *imperialis* Casey. The latter, of which I have seen only the Casey type, differs only in having the lateral parts of the pronotum yellowish red, which may represent a sexual or a racial difference. In view of the extreme scarcity of the material, it is wise to defer the decision on the identity of *nigrosuturalis* and *imperialis* to a future date.

HYPERASPIS BICENTRALIS BICENTRALIS Casey

Plate 3, Figure 75

Hyperaspis bicentralis Casey, 1899, p. 124.

Rounded oval, strongly convex, subhemispherical. In males head yellow with a black bisinuate band or with two black spots on the vertex, pronotum with a very narrow yellow stripe on the anterior and with somewhat broader stripes of the same color on the lateral margins; in females head and pronotum black. Elytra with a large circular red discal spot located closer to the margin than to the suture and in front of the middle of the length of the elytron. Punctulation of the upper surface dense but fine, that of the under side dense but much coarser. Mouth parts, front legs, tibiae and tarsi of the middle and hind legs reddish brown, the whole abdomen or only its sides piceous. Prosternal carinae medium long, a part of the femoral lines subparallel to the posterior margin of the segment. Genitalia (pl. 4, fig. 117) resembling those of *signata* but penis relatively longer and narrower.

Length of the body, 2.6-3.2 mm.; width, 2.2-2.7 mm.

Geographic distribution.—Localities as follows:

Texas: Austin, New Brownfels, La Vaca County, Kerrville, Victoria, Dallas, Paris, Uvalde, College Station, Cypress Mills.
Oklahoma: Mountain Park (on *Lecanium corni*).

HYPERASPIS BICENTRALIS MAJOR, new subspecies

Differs from the type form by a large size, a pale orange or yellow color of the discal spot, and a darker coloration of the under side of the body. In females head, pronotum and under side black, antennae and tarsi dark piceous; in males head, a narrow stripe on the anterior and a somewhat wider one on the lateral margins of the pronotum yellow, mouth parts, tibiae and tarsi of the front and middle legs brown. Genitalia unknown.

Length of the body, 3.5-3.7 mm.; width, 3.0-3.1 mm.

Type and four paratypes.—U.S.N.M. No. 54203.

Geographic distribution.—Locality as follows:

Illinois: Riverside (4 ♂♂ and 1 ♀ including the type, Geo. M. Greene, NMC).

Remarks.—This is a well-pronounced race of *bicentralis* or else an independent species: the lack of material from States lying between Illinois and Texas does not permit a final decision at present.

HYPERASPIS CENTRALIS WICKHAMI Casey

PLATE 3, FIGURE 74

Hyperaspis wickhami CASEY, 1899, p. 124.
Hyperaspis centralis (Mulsant) BOWDITCH, 1902, p. 207.

Body subhemispherical. In males head yellow, pronotum with subquadrate yellow spots laterally and a yellow anterior margin; in females head black, pronotum with yellow lateral spots. Elytra with an orange-yellow spot located clearly posteriorly from the middle of the length of the elytron, closer to the margin than to the suture; the spot rounded or, in individuals in which it is very large, longitudinally oval. Punctulation dense and strong, especially on the sides of the metasternum. In males mouth parts and legs yellow, epimera of the mesosternum white, in females mouth parts, tibiae and tarsi brown; sides of the abdominal sternites piceous in both sexes. Prosternal carinae and femoral lines as in *bicentralis*. Penis (pl. 4, fig. 121) much shorter than the paramera, very short and broad, one side strongly concave, the other convex with a triangular process, the distal end obliquely cut off. Paramera broader than in other species of binotata group. Female genitalia unknown.

Length of the body, 2.8-3.5 mm.; width, 2.1-2.8 mm.

Geographic distribution.—Localities as follows:

Texas: Brownsville (type, CC), Esperanza Ranch, San Tomas, Los Borregos, Laredo, San Diego, Uvalde, Austin.

Remarks.—Bowditch (1902) believed *wickhami* to be a straight synonym of *centralis*. I have seen *centralis* from Loreto, Baja California; from Eldorado, Sinaloa, Santiago Esquintla, Veracruz, Cordoba, Tepic, Guadalajara, and Salina Cruz, Mexico; Tegucigalpa, Honduras; Granada and Chinandega, Nicaragua; and from Costa Rica (all at NMC). They are smaller than the representatives of the species from the United States, and somewhat more strongly and densely punctured. In view of this, I believe it expedient to retain *wickhami* as a subspecific name. The location of the elytral spot in *centralis* and *wickhami* is such that it is difficult to decide whether a discal or an apical spot is involved, although the former seems to me most probable.

HYPERASPIS CENTRALIS PLAGIATA, new subspecies

PLATE 3, FIGURE 82

Less convex than *wickhami*, the yellow margins of the pronotum in the male more strongly developed, elytra with a large red spot extending from two-fifths to four-fifths of the length and from the inner third to the outer sixth of the width, the outline somewhat uneven. Punctulation less strong than in *wickhami*. Genitalia unknown.

Length of the body, 2.8 mm.; width, 2.1 mm.

Type.—U.S.N.M. No. 54204.

Geographic distribution.—Locality as follows:

Maryland: 2.3 miles east of Piney Point (1 ♂, type, H. S. Barber, NMC).

Remarks.—Only a single male of this form is available. It differs from *wickhami* markedly both in body shape and in coloration and may prove to be a separate species.

HYPERASPIS OCULIFERA Casey

PLATE 1, FIGURE 36

Hyperaspis oculifera CASEY, 1908, p. 415.

Differs from *centralis* and from *wickhami* by appreciably smaller body size, denser and stronger punctulation of the pronotum and the elytra, position of the spot, which is about equidistant from the suture and the external margin, and the shape of the head, which is relatively longer and narrower in *oculifera*. Male genitalia (pl. 4, fig. 112) resemble those of *wickhami*, except that size is smaller. The capsule of the spermatheca retort-shaped, the proximal portion small, with a very small appendix.

Length of the body, 2.1-2.5 mm.; width, 1.6-2.0 mm.

Geographic distribution.—Localities as follows:

Arizona: Benson (type CC, also Th. Dobzhansky collection), Santa Catalina Mountains, Tucson, Santa Rita Mountains, Huachuca Mountains (6,000 feet; D. J. and J. N. Knull, SC), Tubac (CASC), Nogales (CASC).

Remarks.—It is possible that *oculifera* will prove to be only a subspecies of *centralis*, although the differences between them appear to be rather considerable. The forms *oculifera-centralis-wickhami* may be arranged in a graded series with respect to size and punctulation.

HYPERASPIS RIVULARIS, new species

PLATE 3, FIGURE 81

Broadly oval, strongly convex. Head yellow in males, black in females; pronotum in both sexes with subquadrate yellow spots laterally, the inner margin of the spots arcuate or straight, in males also with a yellow anterior margin. Elytra with a single yellow or orange discal spot, round or slightly transverse, in one individual (from southern Illinois) extended posteriorly as far as the apical fourth, the center of the spot lying distinctly in front of the middle of the length of the elytron, equidistant from the suture and the lateral margin. Punctulation of the upper surface dense but rather fine, that of the under side dense but stronger. Legs yellow with fuscous femora in both sexes, the abdomen dark piceous. Prosternal carinae as in *bicentralis*, femoral lines more evenly arcuate, not reaching the posterior margin. Genitalia unknown.

Length of the body, 2.2-3.0 mm.; width, 1.7-2.3 mm.

Type and five paratypes.—U.S.N.M. No. 54205.

Geographic distribution.—Localities as follows:

Kentucky: Frankfort (1 ♂, type, H. Soltau collection, now in NMC).
Illinois: southern part (1 ♀, 1 ♂, H. Soltau collection, now in NMC).
Missouri: St. Louis (3 ♀♀, H. Soltau collection, now in NMC).

Remarks.—This species is close to *bicentralis,* but its pronotal markings resemble more those of *centralis.* I believe *rivularis* is without doubt a separate species.

HYPERASPIS TUCKERI Casey

PLATE 1, FIGURE 12

Hyperaspis tuckeri CASEY, 1924, p. 162.

Oval, moderately convex. In the male head, mouth parts, and legs except the hind femora yellow, pronotum with a broad yellow stripe on the lateral and a narrow one on the anterior margin. Elytra with an orange-red spot on the disk, extending from basal fourth to apical third of the length, and from inner two-fifths to outer seventh of the width. Punctulation of the upper surface dense and fine, that of the under side very dense and rather strong. Genitalia unknown.

Length of the body, 2.8 mm.; width, 2.1 mm.

Geographic distribution.—Locality as follows:

Arizona: near Tucson (1 ♂, type, J. F. Tucker, CC).

Remarks.—I have seen only the type of this species. Casey's description of it is inaccurate in stating that the punctulation of the upper surface is "not close, very small and inconspicuous." Neither can I agree with Casey in placing this species as a relative of *connectens,* since it clearly belongs to the *binotata* group.

HYPERASPIS BIGEMINATA (Randall)

PLATE 3, FIGURE 84

Coccinella bigeminata RANDALL, 1838, p. 32.—MULSANT, 1850, p. 1050.—LECONTE, 1880, p. 188.—CASEY, 1899, p. 122.
Hyperaspis guexi MULSANT, 1850, p. 687.—LECONTE, 1880, p. 189.

Rounded oval, strongly convex. In males head, subquadrate spots on the lateral parts of the pronotum, and a narrow stripe on the anterior margin of the pronotum yellow; in females head black, pronotum with yellow spots laterally which are longer than wide and less often subquadrate. Elytra with a medium-sized, orange-red, rounded or slightly transverse apical spot located closer to the margin than to the suture. Punctulation throughout dense and strong, especially so on the sides of the metasternum and on the middle of the first abdominal sternite; the interstices on the head and the pronotum distinctly alutaceous, on the elytra polished. Tibiae and tarsi of all legs and parts of the femora of the front and middle ones yellow in males, only tarsi and tibiae pale in females. Prosternal carinae reaching far forward, femoral lines practically attaining the posterior margin of the segment, their outer parts feebly or not at all angular. Paramera very short and broad, penis (pl. 4, fig. 119) very short, ax-shaped. Capsule of the spermatheca large, retort-shaped.

Length of the body, 2.9-3.2 mm.; width, 2.2-2.5 mm.

Geographic distribution.—Localities as follows:

Ontario: Scotia Junction (Wenzel, SC).
Maine: Summit of Mount Katahdin (NMC).
New Hampshire: White Mountains, Mount Washington.
New York: Top of Mount Whiteface, Mount Marcy, Adirondack, West Danby, Yaphank, Potsdam.
New Jersey: Lakehurst.
District of Columbia: Washington.
Virginia: Nelson County.
North Carolina: Southern Pines.
Georgia: St. Catherine Island.
Florida: Orange County, Fort Myers, Lakeland, Enterprise, Miami (on *Protopulvinaria pyriformis*).
Michigan: Whitefish Point, Marquette, Golden Ledge, Ann Arbor, Horn Mountain.
Indiana: Vigo County.
Texas: Beaumont (on *Eriococcus quercus*), Victoria, Cypress Mills, New Braunfels, College Station, Dallas, Forth Worth.

HYPERASPIS GEMINA Leconte

Plate 3, Figure 80

Hyperaspis gemina Leconte, 1880, p. 188.

Broadly oval, moderately convex. Head yellow in both sexes, in females sometimes infuscate on the clypeus; pronotum black with a broad yellow margin laterally and a black anterior margin. Elytra with a transverse yellow apical spot, the spot constricted at about the middle of its width and showing a tendency to disintegrate into separate ones, an inner and an outer, of which the latter is smaller than the former. Punctulation of the head and the pronotum rather dense but fine, interstices delicately alutaceous, that of the elytra moderately strong with polished interstices, that of the under side dense and strong. Under side dark brown, mouth parts and legs brownish yellow, abdomen piceous brown. Prosternal carinae reaching to within a short distance from the anterior margin, femoral lines evenly rounded. Genitalia unknown.

Length of the body, 2.8-3.9 mm.; width, 2.1-3.1 mm.

Geographic distribution.—Localities as follows:

Virginia: Fortress Monroe (3 individuals, NMC).
North Carolina: Wenona (1 ♀, F. Sherman, NMC), Wilmington (3 individuals, W. T. Davis, C. W. Leng collection).

Remarks.—Leconte (1880) records this species for Georgia and Texas, from where I have seen no specimens. It seems to be rare and to have no close relatives; it is placed near *bigeminata* only provisionally.

HYPERASPIS UNIFORMIS Casey

PLATE 1, FIGURE 14

Hyperaspis uniformis CASEY, 1924, p. 162.

Oblong oval, rather strongly convex, sides of the elytra weakly arcuate, broadly rounded posteriorly. In the male the head, mouth parts, prosternum, legs, and the abdomen except the middle testaceous, pronotum with a narrow yellow stripe on the anterior and with a much broader one on the lateral margins. Elytra solid black with a barely perceptible bluish luster. Punctulation of the upper surface, especially of the elytra, very fine and rather sparse, that of the under side denser but also rather fine. Genitalia unknown.

Length of the body, 3.0 mm.; width, 2.1 mm.

Geographic distribution.—Locality as follows:

North Carolina: Southern Pines (1 ♂, type, Manee, CC).

Remarks.—Two individuals belonging to different species stand in Casey's collection under the name "*uniformis.*" The above description applies to the first of them, the type. The other is an undescribed species; the differences between the two are stated in Casey's paper (1924). It does not seem advisable at present to give a name to the second species. As to *uniformis* it seems best to place it in *binotata* group, although it is a rather aberrant form whose relationships could be determined only on basis of further material.

VII. POSTICA GROUP

Here belong several species living in the western United States. As a whole, this group is related to the preceding one. The elytral pattern consists of an apical spot, to which may be added a humeral one forming a rudimentary marginal vitta.

HYPERASPIS POSTICA Leconte

PLATE 1, FIGURE 15

Hyperaspis postica LECONTE, 1880, p. 188.—CASEY, 1899, p. 127.

Oval, moderately convex. In males head yellow with a black fascia on the vertex frequently covered by the margin of the pronotum; in females head black. Pronotum in both sexes with a moderately broad yellow stripe on the lateral margins. Elytra with a yellow apical spot lying much closer to the margin than to the suture, transversely oval or wedge-shaped, its outline well defined. Punctulation of the upper surface moderately dense but fine, interstices nonalutaceous, that of the under side denser and stronger, especially on the metasternum. In males legs brownish yellow, the abdomen brownish piceous; in females femora and tibiae dark brown, abdomen brownish black with piceous sides and tip. Prosternal carinae low, femoral lines almost reaching the posterior margin of the segment, running for a distance parallel to the latter, their outer parts angular. Penis (pl. 5, fig. 137) and the paramera very long and slender, the former as long as, or longer than, the latter, gradually narrowing distally, the tip hook-shaped. Female genitalia unknown.

Length of the body, 2.3-3.1 mm.; width, 1.7-2.2 mm.

Geographic distribution.—Localities as follows:

British Columbia: Kaslo (R. P. Currie, NMC), Vernon, Salmon Arm (H. B. Leach, SC), Nanaimo (E. P. Van Duzee, CASC).

Idaho: Cow Creek (6,400 feet; R. W. Haegele, University of Idaho collection).

Oregon: 14 miles East of Mitchell (3,750 feet; H. A. Scullen).

Utah: Ogden (NMC).

California: Weott, Humboldt County; Twin Rocks, Mendocino County; Carrville; Nash Mine, Trinity County; Siskiyou County; Cayton; McCloud; Castle Crag; Shasta Springs; Yreka; Oroville; Twain; Portola, Plumas County; Facht, Lassen County; Lyons Dam, Tuolumne County; Yosemite; Wawona; Big Bend Mountain; Pentz, Butte County; Placer County; Truckee; South Fork Kings River; Sequoia Park; Kaweah; Atwood Mill, Tulare County; Coleville, Mono County; Mount Tamalpais; Lagunitas; Fort Baker; Mill Valley; Milbrae; Sobre Vista, San Mateo County; Alameda; Redwood City; Santa Cruz; Carmel; Santa Barbara County; Mohawk; San Diego.

Arizona: Hualpai Mountains (D. J. and J. N. Knull, SC).

Remarks.—This species varies greatly in body shape as well as in size and shape of the apical spot, and may possibly prove to be a composite of several fairly distinct races. In particular, a series of individuals from Marin County, Calif. (SC), shows all degrees of the disappearance of the spot, and almost certainly represents a local race.

HYPERASPIS ELLIPTICA Casey

PLATE 1, FIGURE 13

Hyperaspis elliptica CASEY, 1899, p. 126.
Hyperaspis elliptica angustula CASEY, 1899, p. 127.

Resembles *postica,* but body size larger, distinctly more elongate, punctulation of the elytra stronger. Under side very dark piceous, tibiae and tarsi yellowish in males, brown in females. Femoral lines angular externally. Genitalia unknown.

Length of the body, 2.6-3.2 mm.; width, 1.6-2.0 mm.

Geographic distribution.—Localities as follows:

British Columbia: Kaslo (R. P. Currie, NMC).
Montana: Helena (NMC).
Washington: Easton (A. Koebele, NMC).
California: State record (type of *elliptica,* CC), Mendocino County (type of *angustula,* CC, also San Diego Museum collection), Huntington Lake (E. P. Van Duzee, CASC).

Remarks.—This species is closely related to *postica* but appears to be a separate type, despite the overlapping geographic distribution. Casey's *angustula* is merely an individual variant and may be treated as a synonym.

HYPERASPIS NUNENMACHERI Casey

PLATE 3, FIGURE 85

Hyperaspis nunenmacheri CASEY, 1908, p. 417.

Broadly oval, moderately convex. In males head yellow with a black fascia on the vertex, pronotum with a narrow yellow lateral margin produced along the anterior margin as far as the inner edge of the eye; in females head and pronotum black. Elytra with orange-yellow humeral and apical spots, the former extending from the humeral angles to one-sixth of the length of the outer margin, narrowing posteriorly; the latter rather small, transversely oval, located much closer to the margin than to the suture. Punctulation of the upper surface rather dense but moderately strong, interstices non-alutaceous, that of the under side stronger. Tibiae and tarsi, in males also parts of femora yellow. Prosternal carinae well developed, the space between them narrow, reaching far forward; femoral lines evenly arcuate. Penis (pl. 6, fig. 153) somewhat shorter than the paramera, of the same type as in *postica* but relatively much shorter and broader. Female genitalia unknown.

Length of the body, 2.7-3.3 mm.; width, 2.0-2.4 mm.

Geographic distribution.—Localities as follows:

Washington: State record (Morrison, NMC).
Oregon: Celestin (E. P. Van Duzee, CASC).
Idaho: Boise (NMC).
California: Marin County, Santa Clara County, San Mateo County, San Francisco (SC, CASC), Riverside (type, CC), Plumas County (C. W. Leng collection).

Remarks.—The two individuals from Washington and Idaho are less broadly oval than the California ones; they may belong to a separate race.

HYPERASPIS OCULATICAUDA Casey

PLATE 1, FIGURE 18

Hyperaspis oculaticauda CASEY, 1899, p. 127.

Resembles *postica,* but is easily distinguishable from the latter owing to its small size. Oval, moderately convex. In males head yellow with a bisinuate black vitta on the vertex, black in females; pronotum in both sexes with rather narrow, well-defined yellow stripes on lateral margins. Elytra with a well-defined yellow apical spot, transversely oval or subquadrate in shape, located closer to the margin than to the suture. Punctulation of the pronotum dense and fine, interstices very delicately alutaceous, that of the elytra as dense but decidedly stronger, interstices nonalutaceous, that of the under side relatively fine, except on the sides of the metasternum where it is dense and strong. Under side brownish black, mouth parts and legs brownish, lighter in males than in females. Prosternal carinae strong, almost reaching the anterior margin, femoral lines angular externally, attaining the posterior margin of the segment. Genitalia unknown.

Length of the body, 1.8-2.2 mm.; width, 1.3-1.6 mm.

Geographic distribution.—Localities as follows:

Oregon: Celestin (E. P. Van Duzee, CASC), Klamath Falls (E. C. Van Dyke, CASC).

California: Hoop Valley; Trinity River (type CC); Yreka; Carrville; Trinity County; Siskiyou County; Cayton, Shasta County; Shasta Springs; Tallac; Lake Tahoe; South Fork Kings River; Placer County; Lassen County; Plumas County; Mendocino County; Lakeport; Sisson; Oroville; Cole; Milbrae; Lagunitas; Mount Tamalpais; Muir Woods; Brentwood; Fort Baker; San Francisco; Berkeley; Alameda; Pacific Grove; Carmel; Santa Cruz County; Los Angeles County; Bishop.

Nevada: Carson City (J. N. Knull, SC), Reno (large series, F. E. Blaisdell, CASC).

HYPERASPIS EFFETA Casey

PLATE 1, FIGURE 11

Hyperaspis effeta CASEY, 1899, p. 127.

Very similar to *oculaticauda,* differs principally in having the apical spot much smaller, rounded or slightly transversely oval, with suffused boundaries. The general pigmentation tends toward brown instead of black, in apparently mature individuals elytra as well as the pronotum piceous, under side from dark to light piceous brown. Punctulation of the upper surface finer, there being less difference between the punctures on the elytra and on the pronotum in *effeta* than there is in *oculaticauda*. Genitalia unknown.

Length of the body, 1.8-1.9 mm.; width, 1.3-1.4 mm.

Geographic distribution.—Localities as follows:

Oregon: Klamath Falls (1 ♀, E. C. Van Dyke, CASC).

California: Placer County (1 ♂, type, CC, 1 ♀, A. Koebele, NMC); Lake Tahoe (1 ♂, NMC); Cayton, Shasta County (1 ♀, E. P. Van Duzee, CASC); Glen Alpine (1 ♀, CASC).

Remarks.—*H. effeta* and *oculaticauda* are so similar that the distinction between them may perhaps be questioned. The few specimens that I have seen appear to have slight but consistent differences in their habitus, which, together with their overlapping distribution, make me believe that they represent distinct species.

HYPERASPIS SUBDEPRESSA Casey

PLATE 1, FIGURE 16

Hyperaspis subdepressa CASEY, 1899, p. 127.

Elliptical, subdepressed. In males head yellow with a transverse black fascia on the vertex, in females head black; pronotum in both sexes with a yellow lateral margin, the inner boundary of the yellow vitta nubilate. Elytra with a yellow humeral spot and a small nubilate yellow apical one. Punctulation rather dense and strong, interstices not alutaceous. In females the under side piceous, in males mouth parts and legs, except the hind femora, grayish yellow. Genitalia unknown.

Length of the body, 2.1-2.3 mm.; width, 1.4-1.6 mm.

Geographic distribution.—Localities as follows:

California: Alameda County (1 ♀, type, CC, 1 ♂, A. Koebele, NMC), Dixon (1 ♂, E. P. Van Duzee, CASC), Paraiso Hot Springs (1 ♀, L. S. Slevin, CASC).

Remarks.—Casey's type is a single badly preserved female which may represent an incompletely hardened specimen. The other specimens which I have seen differ from the type in being less narrowly elliptical, in having larger humeral spots, and the apical spots less nubilate in outline. This species seems to be close to *effeta*, but on the other hand to have a resemblance to *dissoluta* from which it differs by its small size.

VIII. TAENIATA GROUP

Here belong several species inhabiting western and southern United States, some of which are so variable and so highly differentiated geographically that they were quite needlessly split into numerous specific units, which in reality are only geographic races or even nongeographic variants. The elytral pattern is very diversified; the marginal spot is present in most species, frequently alone. It may, however, become fused with the humeral one forming a marginal vitta; discal and apical spots may also be present and fused with the marginal one, making the background of the elytra pale instead of black. Penis and the paramera usually rather elongate, the former tongue-shaped. Capsule of the spermatheca retortlike, the connecting duct long.

HYPERASPIS TAENIATA TAENIATA Leconte

PLATE 1, FIGURE 20

Hyperaspis taeniata LECONTE, 1852, p. 134; 1880, p. 187.—CASEY, 1899, p. 125.

Rather broadly oval, moderately convex, somewhat obtusely rounded behind. In males head yellow with a bisinuate black stripe on the vertex, pronotum with a narrow yellow stripe on lateral margins which in most individuals is produced for a varying distance on the anterior margin; in females head and pronotum black. Elytra with an orange-yellow or yellow marginal vitta beginning at the humeral angles, extending past the middle of the length of the external margin, and strongly expanded inward in its posterior part; the expanded part of the vitta very irregular in outline and variable in extent but always reaching to the inner half of the width of the elytron (the expanded part of the vitta obviously represents a fusion of the marginal vitta with a discal spot). Pronotum and the elytra almost equally finely and moderately densely punctulate, punctulation of the under side denser but fine, except on the prosternum and the sides of the metasternum where it is denser and coarser. Under side dark piceous or black, in males mouth parts, front legs, tibiae and tarsi of the middle and hind legs yellow, in females tibiae and tarsi yellow brown. Prosternal carinae well developed, fused together in front of the middle of the length of the segment, femoral lines running for a distance parallel to the hind margin of the first sternite, their outer parts angular. Penis (pl. 6, fig. 156) somewhat shorter than the paramera, the latter slender, basal plates short. Basal portion of the spermatheca short and broad, appendix rather small.

Length of the body, 2.2-3.0 mm.; width, 1.7-2.2 mm.

Geographic distribution.—Localities as follows:

California: Los Angeles County (Coquillett, NMC, F. T. Scott, SC, CASC), Redondo Beach, San Diego, Poway, Pasadena, Palm Springs, Santa Barbara County (P. H. Timberlake collection, CASC), San Bernardino, Mojave (F. T. Scott, SC), Kern County (SC), Tulare County (F. T. Scott, SC), see also under *significans*.

Utah: Logan (F. Marlatt, NMC).

HYPERASPIS TAENIATA NEVADICA Casey

Hyperaspis nevadica Casey, 1899, p. 125.

Less broadly oval than the typical *taeniata*, the yellow vittae on the pronotum in males not produced along the anterior margin, the marginal vitta of the elytra yellow, gradually expanded caudad, its maximum width less than one-third of that of the elytron, the interior outline smooth and clearly defined, punctulation of the upper surface somewhat finer. Mesosternal epimera in the male white. Femoral lines more evenly arcuate, their parts running parallel to the posterior margin of the segment very short. Genitalia as in the typical form.

Length of the body, 2.3-3.0 mm.; width, 1.7-2.1 mm.

Geographic distribution.—Localities as follows:

Idaho: Twin Falls, Filer, Burley, Tuttle, Hansen, Hubbs Butte, Bliss, Boise, Hagerman, Murtaugh, Paul, Declo, Castleford, Hammett, Buhl, Gooding, Hollister, Wendell, Oakley.
Oregon: Harvey County, Hermiston.
Utah: American Fork Canyon (NMC), Salt Lake City (CASC).
Nevada: Reno (type, CC), Elko, Carson City, Lovelock.
Arizona: Pima Mountains (NMC), Hualpai Mountains (SC).
California: Bishop (CASC), Independence (CASC), Mount Wilson (CASC).

Remarks.—This is a well-marked subspecies. Individuals from Arizona, however, have the marginal vitta on the elytra more rapidly expanding caudad, constituting a transition to subspecies *significans*. No intermediates between *nevadica* and the typical *taeniata* have been seen, however; it is possible that their distribution ranges are separated by the Sierra Nevada Mountains, where the species does not occur.

HYPERASPIS TAENIATA PERPALLIDA, new variety

Plate 1, Figure 21

Pronotum in the female with a broad yellow vitta on the lateral margins, not produced along the anterior margin; head black. Elytra yellow, rimmed with black, the black part very narrow on the external margin, somewhat expanding caudad, forming a broad sinuate sutural vitta, and a still broader basal one sharply constricted at the humeral angles. Coloration of the under side in the female like that in the male of the typical form. Male unknown. Genitalia unknown.

Length of the body, 2.7 mm.; width, 1.9 mm.

Type.—U.S.N.M. No. 54206.

Geographic distribution.—Localities as follows:

California: Sacramento County, Grand Island (1 ♀, type, SC, now in NMC).

Remarks.—This is a variant with extremely lightly colored elytra, in which, in addition, the under side of the female assumes the pigmentation found in the male of the type form. Its exact status cannot be established since only a single specimen is available: it may prove to be a subspecies or a nongeographic form.

HYPERASPIS TAENIATA PALLIDULA, new variety

Differs from the typical *taeniata* by a greatly expanded marginal vitta, and by the presence of a rather large, transversely oval apical spot, showing a tendency toward confluence with the vitta. Mesosternal epimerae yellow in the male. Genitalia unknown.

Length of the body, 2.6-2.8 mm.; width, 1.8-2.0 mm.

Type.—In collection of F. T. Scott.

Paratype.—U.S.N.M. No. 54207.

Geographic distribution.—Locality as follows:

California: Kern County (1 ♂, type, and 1 ♀, F. T. Scott, SC).

Remarks.—This form is intermediate between variety *perpallida* and *taeniata taeniata*. F. T. Scott's collection contains two individuals of the latter form from Kern County in which the marginal vittae are strongly expanded but which have no trace of apical spots. It appears, then, that *pallidula* is a geographically restricted individual variation. If *perpallida* proves to be a subspecies, the population containing *pallidula* should be classified as another subspecies bridging the gap between *taeniata taeniata* and *taeniata perpallida*.

HYPERASPIS TAENIATA SIGNIFICANS Casey

PLATE 1, FIGURE 24

Hyperaspis significans CASEY, 1908, p. 416.

Differs from the typical form chiefly in coloration. In males head reddish yellow, rather gradually darkening toward the vertex which is black; pronotum with a dull red ill-defined vitta on the lateral margins; in females head brown, becoming black toward the vertex, pronotum solid black or black with a suffused reddish streak in the anterior angles and along the lateral margins. Elytra with a variable orange or red marginal spot extending from one-quarter to three-fifths of the length and from the margin to the middle of the width of the elytron, frequently extended cephalad along the margin to form a marginal vitta; the inner outline of the spot or the vitta is suffused brownish. Punctulation of the upper surface as a rule somewhat denser, finer, and deeper than in the typical form. Under side varying from reddish brown to black. Genitalia similar to those of the typical form, except that the penis (pl. 6, fig. 159) is somewhat shorter and broader.

Length of the body, 2.2-2.5 mm.; width, 1.7-1.9 mm.

Geographic distribution.—Localities as follows:

California: Los Angeles County, Covina, Claremont, Verdemont Cajon Pass, San Diego County (taken on *Opuntia* infested by cochineal scale, F. T. Scott), Coachella Valley (A. P. Dodd, on cochineal and on *Dactylopius tomentosus,* NMC).

Utah: St. George (type, CC, also in C. W. Leng collection).

Arizona: Bright Angel (E. W. Nelson, on *Dactylopius confusus,* NMC), Prescott (NMC).

Remarks.—In the Southwest this subspecies merges into the typical *taeniata;* thus, the specimens from Covina, Calif., have elytral markings yellow instead of red, the head in females and the under side black, the vitta on the pronotum yellow and rather sharply defined instead of suffused. In general, the specimens from Los Angeles County might be classified as belonging to *taeniata taeniata* as well as to *teaniata significans.* Specimens from St. George, Utah, to which the type belongs, range rather toward *nevadica.* The purest representatives of *significans* which I have seen occur in the Coachella Valley, Calif., where the species appears to be very common. Casey (1908) believed *significans* to be related to *pleuralis,* which is certainly not the case.

HYPERASPIS TAENIATA variety CONCURRENS Casey

Hyperaspis concurrens Casey, 1908, p. 416.

Differs from *taeniata significans* in the absence of the spot on the elytron, making the latter completely black. Genitalia identical.

Geographic distribution.—Locality as follows:

Utah: St. George (3 individuals, including the type, in CC, and a large series in NMC).

Remarks.—This appears to be a geographically restricted color variant so far recorded only from Utah. Intermediates between *concurrens* and *significans* are rare or absent despite the fact that they occur together. This indicates that the difference between them is due to a single gene.

HYPERASPIS TAENIATA PALLESCENS, new variety

Plate 1, Figure 23

Body shape, size, and structural characters as in *taeniata nevadica.* Elytra with a marginal vitta reaching to the apical region, greatly expanded inward in the discal region, the expanded part reaching the inner half of the width of the elytron. Genitalia unknown.

Type.—In collection of F. T. Scott.

Paratype.—U.S.N.M. No. 54208.

Geographic distribution.—Locality as follows:

Arizona: Hualpai Mountains (3 ♀♀ including the type, D. J. and J. N. Knull, SC).

Remarks.—This is a derivative from *taeniata nevadica* which is analogous to the derivative from *taeniata taeniata* which is called above variety *pallidula*. F. T. Scott's collection has two more individuals from Hualpai Mountains, which I classify as belonging to *taeniata nevadica*, although these individuals, as well as those of variety *pallescens* show an admixture of the characteristics of *taeniata significans*. Variety *pallescens* is, then, probably a geographically restricted color variant.

HYPERASPIS TAENIATA RUFESCENS, new subspecies

PLATE 1, FIGURE 25

Resembles most closely *taeniata significans*, but head yellow with a black vitta on the vertex in males, black becoming brownish on the clypeus in females. Pronotum with a suffused orange-yellow vitta on the lateral margins in males, black in females. Elytra with a rufous area extending from the margin to the middle of the width of the elytron, and from one-fifth to well past the middle of the length, in some individuals produced toward the humeral angles to form a marginal vitta, the outline of the area suffused internally. Color of the under side ranging from reddish brown to black. Punctulation of the elytra dense and distinctly finer than in *taeniata significans*. Genitalia identical.

Length of the body, 2.3-2.8 mm.; width, 1.7-2.1 mm.

Type and 10 paratypes.—U.S.N.M. No. 54209.

Geographic distribution.—Localities as follows:

Texas: El Paso (type, on *Opuntia*, F. C. Pratt, NMC), Brewster County (on *Coccus* on *Opuntia*, Mitchell and Cushman, NMC), Devil's River (F. C. Pratt, NMC).

New Mexico: Mesilla Park (on *Coccus confusus*, D. Griffiths, NMC).

Colorado: Palisade (W. A. Shands, NMC).

Remarks.—Certain individuals of *taeniata rufescens* are almost identical with individuals of *taeniata significans* from California, except that the punctulation in the former seems to be always finer than in the latter. Despite the closeness of the two, I believe *rufescens* to be worthy of recognition as a subspecies. Not only are the modal points of these two races different, but their geographic areas seem to be separated by a southward extension of the area of *taeniata nevadica*.

HYPERASPIS TAENIATA CRUENTA Leconte

Plate 1, Figure 26

Hyperaspis cruenta Leconte, 1880, p. 187.

More broadly oval than the preceding races of *taeniata,* sides of the elytra less arcuate, more broadly rounded behind. In males head yellow with a black vertex, pronotum with a well-defined, yellow, parallel-sized, rather broad vitta on lateral margins, and a much narrower one on the anterior margins; in females head and the pronotum black. Elytra with a sharply defined yellow marginal vitta extending from the humeral angles to three-fifths of the length; the vitta somewhat expanded posteriorly and constricted at one-sixth of the length by a triangular projection of the black background. Punctulation dense but very fine, that of the pronotum clearly denser than that of the elytra. Under side black or piceous black, in males mouth parts and legs except the hind femora yellow, mesosternal epimera white; in females legs dark brown. Femoral lines run for a certain distance parallel to the posterior margin of the segment. Genitalia as in the typical form, except that the penis (pl. 6, fig. 154) is somewhat narrower and more acuminate toward the distal end.

Length of the body, 2.2-2.8 mm.; width, 1.6-2.1 mm.

Geographic distribution.—Localities as follows:

Texas: Brownsville, Esperanza Ranch (NMC), Columbus (NMC), Goliad (NMC), Uvalde.

Remarks.—This is the most distinctive one among the races of *taeniata.* Perhaps since no representatives of the species are known from central Texas or from northeastern Mexico, no intermediates between *cruenta* and *rufescens* have been observed. I include *cruenta* among the races of *taeniata,* although, admittedly, this course is open to question since the two may prove to be independent species.

HYPERASPIS TAENIATA CRUENTOIDES, new subspecies

Plate 1, Figure 27

Differs from *taeniata cruenta* in having an orange-red marginal vitta on the elytra, the width of the vitta uniform throughout its length or barely greater in its posterior part than at the humeral angles, without, or with merely an indication of, a constriction at the callus. Punctulation of the elytra extremely fine, almost obsolescent on the disk. The shape of the penis intermediate between those in the typical *taeniata* and in *taeniata cruenta,* being closer to the former than to the latter.

Length of the body, 2.7-3.2 mm.; width, 2.1-2.4 mm.

Type and two paratypes.—U.S.N.M. No. 54210.

Geographic distribution.—Locality as follows:

Florida: Bartow Junction (1 ♂, 2 ♀♀, collection of Hubbard and Schwarz, now in NMC).

Remarks.—In certain characters (e.g., punctulation) *cruentoides* differs from the western races of *taeniata* even more than *cruenta* does, yet in others (coloration) it is intermediate between them, thus making *cruenta* less isolated.

HYPERASPIS TAENIATA BINARIA Casey

PLATE 1, FIGURE 30

Hyperaspis binaria CASEY, 1924, p. 165.

Body shape as in *taeniata cruenta* and *cruentoides.* In females head, pronotum, and the under side black, tibiae, tarsi, and sides of the abdominal segments piceous; male unknown. Elytra with an abbreviated dull orange marginal vitta beginning at about one-fifth of the length of the external margin, expanding caudada, and somewhat deflected from the margin in its posterior part; the boundaries of the vitta rather nubilate. Punctulation dense and fine, although somewhat stronger than in *cruentoides,* pronotum feebly alutaceous. Genitalia unknown.

Length of the body, 2.3-2.8 mm.; width, 1.8-2 mm.

Geographic distribution.—Localities as follows:

North Carolina: Southern Pines (1 ♀, type, CC).
Florida: Fort Walton (1 ♀, Geo. Swank, NMC).

Remarks.—This is the easternmost representative of the *taeniata* complex. The material available on *binaria* as well as *cruentoides* being as scarce as it is, the failure to observe intermediates between them is not surprising, but this fact does not seem to me sufficient ground to classify them as independent species. Taken as a whole, the *taeniata* complex is an extremely interesting one. The various subspecies show various recombinations of several characters (color of the elytral markings, their reduction or expansion, punctulation, etc.); certain combinations have become geographically established, others still occur in mixed populations only, and have been classed above as varieties rather than subspecies.

HYPERASPIS OSCULANS Leconte

PLATE 1, FIGURE 29

Hyperaspis osculans LECONTE, 1880, p. 187.—CASEY, 1899, p. 125.

Broadly oval, rather obtusely rounded behind, moderately convex. In males head pale yellow with a black stripe on the vertex, pronotum with a pale yellow vitta laterally expanding anteriorly and as a whole forming a triangular spot; in females head black, pronotum black, or black with a pale streak in anterior angles, or with a pale vitta on lateral margins which is, however, not as broad as in males. Elytra with a marginal spot varying in color from yellowish white to orange yellow, the spot wider than long, reaching inward to from one-quarter to almost one-half of the width of the elytron. Punctulation dense and fine, that of the elytra only slightly stronger than that of the pronotum. Mouth parts, tibiae, tarsi, and tips of femora yellow in males, brown in females; abdomen sometimes piceous on sides. Prosternal carinae strong, in some individuals almost reaching the anterior margin; femoral lines arcuate, just touching the posterior margin, their outer parts not angular. Paramera (pl. 6, fig. 160) short and broad, almost spoon-shaped, penis somewhat shorter than the paramera, very asymmetrical, one side nearly straight while the other forms a large triangular process, the distal end rather rounded. Female genitalia unknown.

Length of the body, 2.5-3.1 mm.; width, 2.0-2.4 mm.

Geographic distribution.—Localities as follows:

California: Cayton, Shasta County; Eldridge, Sonoma County; Santa Clara County; Eldorado County; Camino; Colfax; Ahwahnee; Sequoia Park; Potwisha; Kaweah; Santa Barbara County; Lebec; Mount Lowe; Pasadena; Forest Home; Claremont (SC).

HYPERASPIS PLEURALIS Casey

PLATE 1, FIGURE 28

Hyperaspis pleuralis CASEY, 1899, p. 125.

Broadly oval, rather obtusely rounded behind, moderately convex. In males head yellow with a black stripe on the vertex, pronotum with a yellow lateral margin which is distinctly narrower than in *osculans* but which is, in some individuals, produced for a short distance along the anterior margin; in females head and the pronotum black. Elytra with a marginal spot varying in color from yellow to dull red, semicircular in form, reaching inward to no more than a quarter of the width of the elytron. Punctulation dense and rather strong, much denser on the pronotum than on the elytra. Mouth parts and front legs brownish yellow, middle and hind legs brown in males, in females tarsi dark brown. Prosternal carinae variable, but generally reaching forward to only the middle of the length of the segment; femoral lines as in *osculans*. Paramera (pl. 6, fig. 161) slender, penis relatively very broad, only slightly narrowing distally, the distal end rounded, one side nearly straight and the other with an obtuse process located relatively very close to the base. The capsule of the spermatheca retort-shaped, basal portion with a rather large appendix.

Length of the body, 2.1-2.5 mm.; width, 1.6-2.0 mm.

Geographic distribution.—Localities as follows:

Texas: Finlay (J. O. Martin, CASC), El Paso (type, CC), 20 miles east of El Paso (Th. Dobzhansky).

Arizona: Tucson, Pima Mountains, Santa Rita Mountains, Littlefield, Oracle, Williams, Hot Springs, Ajo, Tonto Basin, Yuma.

California: Truckee, Lebec, Los Angeles County, Monrovia (on *Dactylopius confusus*), Upland, San Bernardino, San Diego County, Grapevine Grade, Kern County, Olancha, Little Lake, Mojave, Panamint Valley, Palm Springs.

Utah: St. George, Salt Lake City (P. H. Timberlake collection, CASC).

Nevada: Glendale.

Remarks.—Individuals of this species from California have larger and yellower spots than those from Arizona and Texas, thus indicating a transition toward *osculans*. No doubt, *osculans* and *pleuralis* are very closely related, but their distribution areas definitely overlap in California, without, however, real intergrades being formed. This fact, as well as the rather considerable morphological differences between them, indicate that they are to be considered separate species rather than races of a single one.

HYPERASPIS PLEURALIS variety ATERRIMA Casey

Hyperaspis aterrima Casey, 1908, p. 416.

Differs from the typical *pleuralis* in having solid black elytra and in having both the lateral and the anterior margins of the pronotum yellow in males. Genitalia of both sexes identical with those of *pleuralis*, as is the body size.

Geographic distribution.—Localities as follows:

Texas: El Paso, Finlay.

Arizona: Hot Springs, Tucson, Phoenix, Yuma.

California: Los Banos, Fresno County, Tulare County (on *Atriplex* infested by a cottony scale, F. T. Scott), Poso Creek, Kern County, Death Valley, Blythe, Imperial County, Palm Springs, San Diego County.

Utah: St. George (type, CC, also a series of specimens in NMC).

Nevada: Overton.

Mexico: Sonora (Koebele, NMC).

Remarks.—The taxonomic status of *aterrima* is a rather perplexing problem. It differs from the typical *pleuralis* in two apparently distinct characters, namely, absence of the elytral spot and presence of a yellow anterior margin of the pronotum in males. These characters show a strong, although not perfect, correlation (there is one male from Hot Springs, Ariz., having black elytra and a black anterior margin of the pronotum). Since, in Coccinellidae, the color patterns of the pronotum and of the elytra are, as a rule, inherited independently, such a correlation would be understandable if *pleuralis pleuralis* and *pleuralis aterrima* were geographically isolated. As a matter of fact, their distributions are nearly identical, and in many localities both are found side by side, although their proportions in different populations are by no means identical. Thus, a fairly large sample from Blythe, Calif. (P. H. Timberlake collection), contains only *aterrima,* whereas east of El Paso, Tex., I have collected more than 100 *pleuralis* and no *aterrima.* Under such circumstances we may be dealing either with color forms differing in one gene, or with independent species. A careful morphological comparison has been undertaken, without any additional difference being detected. This is a very interesting case showing the limitations of a purely morphological method of investigation. The status of *aterrima* could be settled only on the basis of experimental data, which are lacking at present.

HYPERASPIS BIORNATA BIORNATA Nunenmacher

Plate 2, Figure 71

Hyperaspis biornatus Nunenmacher, 1934, p. 18.

Broadly oval, obtusely rounded behind, little convex, pronotum short but wide. In males head yellow with a black stripe on the vertex, pronotum with yellow vittae on the lateral margins very slightly or not at all produced along the anterior margin, the length of the vittae being about twice as great as their maximum width, which is attained near the anterior angles; in females head black, pronotum with yellow vittae laterally which are about three times longer than wide. Elytra with yellow marginal and apical spots, the former located slightly behind the middle of the length of the elytron, almost detached from the margin, rounded or transverse, reaching inward to from one-third to one-half of the width, the apical spots much smaller, obliquely oval, and usually connected with the marginal ones by yellow bridges of varying width. Punctulation of the pronotum rather dense and medium fine, that of the elytra only slightly stronger but not sparser than that of the pronotum, that of the under side very dense and moderately strong. Mouth parts, front legs, tibiae and tarsi of the middle and hind legs brownish yellow in males, tibiae and tarsi piceous in females. Prosternal carinae reaching forward to between two-thirds and three-quarters of the length of the segment, femoral lines arcuate, not touching the posterior margin of the first abdominal sternite. Genitalia very similar to those of *osculans,* except that the penis is much shorter than the paramera.

Length of the body, 2.6-3.0 mm.; width, 2.0-2.3 mm.

Geographic distribution.—Localities as follows:

California: Monterey County (2 ♂♂, 1 ♀, F. T. Scott, SC), Stanford University (1 ♀, G. F. Ferris, NMC), Pinnacles National Monument (1 ♀, 1 ♂, Th. Dobzhansky), Big Sur (1 ♀, CASC), described from Livermore, Alameda County (type not examined by the writer).

Remarks.—In his description, Nunenmacher compares this species with *connectens* (*lengi*), with which it has only a most superficial similarity; *biornata* certainly belongs to the *taeniata* group and is closely related to *osculans,* although it represents undoubtedly a distinct species. The marginal spot in *biornata* lies farther caudad than in its relatives, which is probably due to a change in body shape.

HYPERASPIS BIORNATA ARIZONICA, new subspecies

PLATE 2, FIGURE 61

Body more elongate than in the typical *biornata,* less obtusely rounded behind. Coloration of the head as in *biornata.* Pronotum in the male with a yellow stripe laterally which is more than twice as long as wide, not produced on the anterior margin, in females with a yellow streak laterally which either resembles that in *biornata* or is reduced to the extent that it does not reach either the anterior or the posterior angles. Elytra with a large orange-yellow spot on the external margin extending from three-fifths to seven-eighths of the length, obliquely cut anteriorly and posteriorly, its inner boundary parallel to its outer one, reaching inward to and beyond the middle of the width of the elytron. Punctulation of the pronotum noticeably denser and finer than that of the elytra. Shape of the femoral line unique, compressed from sides, parabola-shaped. Genitalia unknown.

Length of the body, 2.3-3.0 mm.; width, 1.7-2.2 mm.

Type and three paratypes.—U.S.N.M. No. 54211.

Geographic distribution.—Locality as follows:

Arizona: Bright Angel (3 ♀♀, 1 ♂, Barber and Schwarz, NMC).

Remarks.—Despite rather considerable differences between *biornata biornata* and *biornata arizonica* (especially the difference in the shape of the femoral line), I believe them to be races of the same species. The elytral spot in *arizonica* corresponds to enlarged and fused marginal and apical spots of the typical *biornata.*

IX. FIMBRIOLATA GROUP

This group consists of a series of rather closely related forms some of which appear to stand on the very threshold between being races of the same species and independent species. Body oval, moderately convex. Elytra with a yellow or red marginal vitta extending from the humeral angles to within a short distance from the apex; the vitta represents fused humeral, marginal, and apical spots, and in some species breaks up into these constituent parts. Penis about as long as the paramera, acuminate distally, paramera slender, fingerlike, basal plates small. The capsule of the spermatheca retort-shaped, basal portion short but rather broad, with a moderately small appendix.

HYPERASPIS FIMBRIOLATA FIMBRIOLATA Melsheimer

PLATE 3, FIGURE 86

Hyperaspis fimbriolata MELSHEIMER, 1847, p. 180.—LECONTE, 1880, p. 186.—CASEY, 1899, p. 126.
Hyperaspis rufomarginata MULSANT, 1850, p. 661.—LECONTE, 1880, p. 189.
Hyperaspis limbalis CASEY, 1899, p. 126.

Oval, moderately convex. In males head yellow with a black stripe on the vertex covered by the margin of the pronotum, pronotum with a yellow vitta on the lateral margins slightly produced on the anterior margin, the vitta narrow, becoming somewhat broader anteriorly; in females head and pronotum black. Elytra with a yellow or orange marginal vitta which is one-fourth or one-fifth as wide as the elytron, clearly bisinuate, the apical end deflected from the margin but not increased greatly in width, not protracted forward, evenly rounded. Punctulation of the pronotum dense and moderately strong, that of the elytra somewhat less dense and a little stronger, that of the under side dense but rather strong. Legs black, tibiae and tarsi brownish in females, yellowish in males. Prosternal carinae reaching forward to about two-thirds of the length of the segment, femoral lines broad, their middle parts subparallel to the posterior margin of the first abdominal sternite. Penis (pl. 5, fig. 144) long, concave on one side and convex on the other. The proximal part of the spermatheca one and one-half times longer than wide, appendix relatively large.

Length of the body, 2.3-2.8 mm.; width, 1.7-2.0 mm.

Geographic distribution.—Localities as follows:

New York: Rockaway, Pelham.
New Jersey: Emerson.
Maryland: Baltimore.
District of Columbia: Washington.
Virginia: Fortress Monroe.
North Carolina: Black Mountains.
Illinois: Havana, Ashley, Du Bois.

Nebraska: Lincoln.
Kansas: Topeka, West Kansas.
Texas: College Station, Chisos Mountains, Brewster County, Marathon, Thurber, Devil's River, Dallas, Rosser, Laredo, Beeville, Mission, Austin, Uvalde, Gorman, Davis Mountains, Alpine, El Paso.
Colorado: Denver, Pueblo, Florence, Colorado Springs, Palisade, Salida.
New Mexico: Las Vegas, Torrance County, Fort Wingate.
Arizona: Chiricahua Mountains, Huachuca Mountains, Santa Rita Mountains, Nogales, Pinal Mountains, Palmerly, Oracle, Hot Springs, Williams, Globe.
California: Visalia, Riverside (on *Phenococcus colemani*), Selma, Santa Monica, Long Beach, Azusa, Warner's Hot Springs, San Diego, Playa del Rey.

HYPERASPIS FIMBRIOLATA ATLANTICA, new subspecies

PLATE 3, FIGURE 91

More oval than *fimbriolata fimbriolata,* slightly acuminate posteriorly. Punctulation much finer, the interstices between the punctures alutaceous. The marginal vitta ochraceous, narrower than in the typical form, its internal boundary not bisinuate, evenly curved, its width gradually but slightly increasing toward the apex, the apical part only very slightly deflected from the margin, not at all protracted forward. Tibiae and tarsi of all legs brownish yellow, hind tibiae infuscate. Penis (pl. 5, fig. 141) narrower than in the typical form.

Length of the body, 2.3-2.7 mm.; width, 1.6-1.9 mm.

Type and three paratypes.—U.S.N.M. No. 54212.

Geographic distribution.—Localities as follows:

Florida: Capron (type, collection Hubbard and Schwarz, now in NMC), Crescent City (NMC).
Virginia: Fortress Monroe (NMC).
Mississippi: Waveland (H. Soltau collection, now in NMC).

HYPERASPIS FIMBRIOLATA SERENA Casey

PLATE 3, FIGURE 89

Hyperaspis serena CASEY, 1908, p. 417.

Intermediate between *fimbriolata fimbriolata* and *fimbriolata inflexa.* More oblong than the former but not acuminate posteriorly. Punctulation fairly strong, interstices polished. Anterior margin of the pronotum yellow in males. Marginal vitta broad, its apical end dilated, truncate instead of rounded, slightly protracted forward. Genitalia as in *inflexa.*

Length of the body, 2.4-2.5 mm.; width, 1.7-1.8 mm.

Geographic distribution.—Localities as follows:

Massachusetts: Springfield, Tyngsboro.
New York: Whiteface Mountains, Palisades, Van Cortland Park, Westchester County, Mosholu, Babylon, Long Beach, Yaphank.

New Jersey: Lakehurst, Longport, Jamesburg.
Pennsylvania: State record (type, CC).
Michigan: Marquette, Douglas (NMC).

Remarks.—This is a slight race of fimbriolata, as stated above intermediate between the typical form and *inflexa.*

HYPERASPIS FIMBRIOLATA INFLEXA Casey

PLATE 3, FIGURE 87

Hyperaspis inflexa CASEY, 1899, p. 126.

Larger and more oblong than the typical form, not acuminate posteriorly. Anterior margin of the pronotum narrowly yellow in males. Marginal vitta broad, its width about equal to one-fourth of that of the elytron, its interior outline strongly sinuate, the apical end usually not deflected from the margin, strongly expanded, abruptly truncate, and extended forward. Tibiae and tarsi pale. Penis (pl. 5, fig. 140) shorter than the paramera, gradually narrowing from the base distally, the tip rounded.

Length of the body, 2.6-2.9 mm.; width, 1.7-1.9 mm.

Geographic distribution.—Localities as follows:

Minnesota: Grand Marais, Cook County, Niswa, St. Paul, St. Anthony (all in University of Minnesota collection).
Manitoba: Andover (C. V. Riley collection, now in NMC), Aweme (C. W. Leng collection).
North Dakota: Bismarck (type, CC).
Montana: Helena, Bear Paw Mountains (NMC).
Nebraska: Pine Ridge.
Wyoming: Laramie (D. J. and J. N. Knull, SC).
Kansas: Riley County (NMC).
Colorado: Colorado Springs (NMC).
New Mexico: Magdalena (Strickler, NMC).

Remarks.—The individual from New Mexico is intermediate between *inflexa* and the typical form. The rather abundant material from Minnesota might be classed as belonging either to *inflexa* or to *serena.*

HYPERASPIS CINCTA Leconte

PLATE 3, FIGURE 90

Hyperaspis cincta LECONTE, 1858, p. 89; 1880, p. 189.—CASEY, 1899, p. 126.
Hyperaspis nupta CASEY, 1899, p. 126.

Broadly oval, moderately convex. In males head yellow, pronotum with a yellow vitta laterally becoming distinctly broader toward the anterior angles, and with the anterior margin narrowly yellow; in females head and pronotum black. The marginal vitta on the elytra orange, yellow, or cream-colored, very board, its width equaling one-third to more than one-half of the width of the elytron, sharply indented at the callus, and less sharply so at three-quarters of the length, the apical part not dilated, rounded at the tip. Punctulation of the pronotum moderately dense and medium strong, that of the elytra very sparse and fine, in some individuals almost obsolescent, that of the under side rather dense and strong. Mouth parts and legs pale, hind femora usually infuscate, abdomen wholly or partly brownish. Prosternal carinae and femoral lines as in *fimbriolata*. Penis (pl. 5, fig. 139) and the paramera shorter than in *fimbriolata*, tip of the former acuminate. Female genitalia as in *fimbriolata*.

Length of the body, 1.9-2.5 mm.; width, 1.4-1.9 mm.

Geographic distribution.—Localities as follows:

California: Humboldt County (type of *nupta*, CC); Mendota, Fresno County; Selma; Los Banos; El Cajon; Claremont; Mount San Gorgonio; Visalia (a large series reared from *Sueda torreyana* infested by a psyllid, *Aphalara suedae*, F. T. Scott, SC); Inglewood (on *Phenacoccus colemani*, P. H. Timberlake collection); San Diego.

Utah: Salt Lake City (NMC).

Arizona: Grand Canyon (CC).

Remarks.—*Cincta* seems to differ from the races of *fimbriolata* more than the latter differ from each other, and this is the reason for considering the former a separate species. Moreover, the distribution area of *cincta* overlaps that of *fimbriolata* without formation of intermediates.

HYPERASPIS PROTENSA Casey

Plate 1, Figure 19

Hyperaspis protensa Casey, 1908, p. 417.

Elongate oval, subdepressed, sides of the elytra feebly arcuate, bluntly rounded behind, pronotum only slightly longer at the middle than on the sides. In the male head yellow, pronotum with a yellow vitta laterally becoming broader toward the anterior angles, the anterior margin black; in females head and pronotum black. Elytra with a pale yellow marginal vitta, the internal outline of the latter bisinuate, the posterior part strongly deflected from the margin, somewhat constricted and expanded into an apical spot. Punctulation dense but fine and rather shallow, that of the elytra being stronger but less dense than that of the pronotum. Femoral lines fail to reach the posterior margin of the segment. Legs yellow, femora infuscate in females, abdomen piceous. Genitalia unknown.

Length of the body, 1.8-2.1 mm.; width, 1.2-1.4 mm.

Geographic distribution.—Localities as follows:

Arizona: Nogales (type, CC), Tucson (NMC), Santa Rita Mountains (Th. Dobzhansky).

Remarks.—A bridge between the *postica* and *fimbriolata* groups of species, which are not otherwise closely related, seems to be possible if we compare *protensa* with *subdepressa,* for these two species have a definite external similarity. It is therefore especially regrettable that both of them are known in so few specimens that the structure of the genitalia could not be studied.

HYPERASPIS MARGINATA Gaines

Hyperaspis fimbriolata marginatus GAINES, 1933, p. 263.

Broadly oval, moderately convex, sides of the elytra feebly arcuate, bluntly rounded behind. In males head and pronotum piceous yellow, the latter diffusely darker on the posterior margin in front of the scutellum; in females head and pronotum black, the former becoming lighter on the clypeus, the latter with reddish-yellow lateral and anterior margins. Elytra with a pale yellow marginal vitta very slightly deflected from the margin in its posterior quarter or fifth, rather narrow, the internal outline smoothly curved. Punctulation of the pronotum very fine, interstices alutaceous, that of the elytra moderately dense and strong, interstices nonalutaceous, that of the under side dense but fine. Under side brownish black or piceous, mouth parts and legs yellow, sides of the abdomen lighter than its middle. Prosternal carinae close, reaching almost to the anterior margin, femoral lines very flat, far from attaining the posterior margin of the first abdominal sternite, their outer parts flattened long before reaching the sides of the segment. Genitalia unknown.

Length of the body, 2.5-2.8 mm.; width, 1.9-2.2 mm.

Geographic distribution.—Locality as follows:

Texas: College Station (type, Gaines, NMC).

Remarks.—My original impression after examining this form has been that it represents a race of *fimbriolata,* and I have so advised Dr. Gaines. Now I find the differences between the two justify considering them as separate species, especially since both *marginata* and *fimbriolata* occur at the type locality of the former.

HYPERASPIS DISSOLUTA DISSOLUTA Crotch

PLATE 3, FIGURE 93

Hyperaspis dissoluta CROTCH, 1873, p. 379.—LECONTE, 1880, p. 187.—CASEY, 1899, p. 126.

Oval, moderately convex. In males head yellow, pronotum with yellow lateral margins, in females head and pronotum black. Elytra with a yellow marginal vitta and an apical spot; the former extending from the humeral angles to two-thirds of the length, rather narrow, distinctly sinuate, the parts corresponding to the humeral and the marginal spots broader than the intervening part, the apical spot transversely oval, lying closer to the margin than to the suture. Punctulation of the upper surface, especially of the elytra, denser but shallower than in *fimbriolata,* that of the under side dense and strong. Mesosternal epimera white in some individuals of either sex, legs brownish yellow, femora infuscate, abdomen piceous on the sides. Penis (pl. 5, fig. 138) shorter than the paramera, acuminate distally, the convex side with a tubercle lying closer to the base than to the tip. Female genitalia as in *fimbriolata.*

Length of the body, 2.2-2.8 mm.; width, 1.6-2.2 mm.

Geographic distribution.—Localities as follows:

Nevada: State record (SC).

Arizona: State record (NMC).

California: Siskiyou County, Red Bluff, Chico, Sacramento, Auburn, Lodi, Stockton, Merced, Visalia (a large series, F. T. Scott, SC), Selma, Sequoia Park, South Fork Kings River, Lindsay, Bakersfield, Tejon, Mount Pinos, Lakeport, Guerneville, Mill Valley, Alameda, Piedmont, Oakland, Stanford University, Carmel, Pasadena, Victorville.

HYPERASPIS DISSOLUTA COLORADANA Casey

PLATE 3, FIGURE 94

Hyperaspis coloradana CASEY, 1908, p. 417.

Larger, more elongate, and less convex than the typical form, punctulation of the elytra somewhat stronger, the marginal vitta on the elytra a little or not at all sinuate, its width subequal in all parts. Genitalia identical with those of the typical form.

Length of the body, 2.4-3.0 mm.; width, 1.8-2.1 mm.

Geographic distribution.—Localities as follows:

Montana: Gallatin County (NMC).

Minnesota: Cook County, Shore of Lake Superior (University of Minnesota collection).

Oregon: State record (University of Minnesota collection).

Colorado: Boulder (type, CC).

Texas: Val Verde County (D. J. and J. N. Knull, SC), Austin, Sheffield (T. O. Martin, CASC).

Remarks.—The differences between *dissoluta dissoluta* and *dissoluta coloradana* are so slight that it is questionable whether they are worth treating as distinct subspecies. The specific distinction between *dissoluta* and *fimbriolata* is, on the other hand, clear enough: they occur together without forming intergrades.

HYPERASPIS SANCTAE-RITAE, new species

Plate 3, Figure 92

Broadly oval, moderately convex. Head in males yellow, pronotum with narrow yellow vittae laterally, the width of the vittae increasing anteriorly, the anterior margin of the pronotum black; females unknown. Elytra with a yellow marginal vitta extending from the humeral angles to nine-tenths of the length, the interior outline of the vitta strongly bisinuate, the apical end deflected from the margin, rounded, not protracted forward, somewhat wider than the basal part of the vitta. Punctulation of the pronotum dense and strong, that of the elytra less dense but stronger, and that of the under side moderately dense and strong. Legs brownish yellow, hind femora infuscate, mesosternal epimera black, sides of the abdomen piceous. Penis (pl. 5, fig. 142) nearly as long as the paramera, very narrow, sides subparallel for two-thirds of the length, the distal end truncate. Paramera long and slender. Female genitalia unknown.

Length of the body, 2.2-2.5 mm.; width, 1.3-1.5 mm.

Type and two paratypes.—U.S.N.M. No. 54213.

Geographic distribution.—Localities as follows:

Arizona: Santa Rita Mountains (3 ♂♂, including the type, collection Hubbard and Schwarz, now in NMC), Nogales (1 ♂, Koebele, CASC).

Remarks.—This species is set apart from its relatives known to me principally by the structure of its genitalia. It appears to be related to *psyche* more closely than to the rest.

HYPERASPIS PSYCHE Casey

Plate 3, Figure 88

Hyperaspis psyche Casey, 1899, p. 125.

Oval, moderately convex, sides of the elytra feebly arcuate, obtusely rounded behind. In males head yellow with a black stripe on the vertex, pronotum with a yellow stripe on the lateral margin, the stripe broader anteriorly than posteriorly, the anterior margin black; in females head and pronotum black. Elytra with yellow humeral, marginal, and apical spots; the humeral one triangular; the marginal more or less semicircular; the apical one rather small in some individuals and the largest of the three in others, rounded or transversely oval; in two individuals from Lebec (see below) traces of a longitudinally oval discal spot are present. Punctulation moderately sparse and fine, that of the elytra stronger than that of the pronotum. Legs brownish yellow, femora infuscate, abdomen more or less piceous. Femoral lines broad, their middle parts running parallel to the hind margin of the segment. Penis (pl. 5, fig. 143) markedly shorter than the paramera, rounded at the distal end, the convex side devoid of any sharp prominence, paramera long and slender. Female genitalia as in *fimbriolata*.

Length of the body, 2.3-2.7 mm.; width, 1.7-1.9 mm.

Geographic distribution.—Localities as follows:

California: Alameda County (type, CC), Muir Woods, Fairfax, Lagunitas, Pinnacles National Monument, Contra Costa County, Sequoia National Park, Kern County, Lebec (a fairly large series, F. T. Scott, SC), Mojave, Pasadena, Forest Home, San Diego.

Remarks.—The population of Lebec differs from others by having the spots enlarged and in some cases having discal spots which are not present in any other species of *fimbriolata* group. It is possible that a separate race is here involved.

X. DISCONOTATA GROUP

Here belong a large number of Mexican and Central American forms. In the United States this group is represented by an aberrant species (*disconotata*) and by a species (*trifurcata*) which more nearly resembles its tropical relatives. The color pattern of the elytra consists of the whole typical set of the spots (i.e., five on each elytron), which by confluence may give rise to a series of black designs on a pale background which at first sight are difficult to derive from the type pattern. Penis and the paramera long, the former with a sharp toothlike tubercle on one side. Capsule of the spermatheca retort-shaped, gradually passing into the connecting duct.

HYPERASPIS DISCONOTATA DISCONOTATA Mulsant

PLATE 2, FIGURE 65

Hyperaspis disconotata MULSANT, 1850, p. 653.—LECONTE, 1880, p. 187.—CASEY, 1899, p. 127.

Oval, little convex, maximum width of the body reached in front of the middle of the length, somewhat acuminate posteriorly. In males head yellow with a black fascia on the vertex that is wider on the sides than in the middle, pronotum with yellow stripes on the lateral and anterior margins, the stripes of a uniform width throughout; in females head and pronotum black. Elytra with five yellow spots of the basic pattern of the genus; humeral spot triangular, its side adjacent to the external margin about twice as long as that adjacent to the basal margin; basal spot, separated from the humeral one merely by a black line, subtriangular; marginal spot three or more times longer than wide; discal spot longitudinally oval, at least twice as long as wide; apical spot transversely oval. Punctulation of the pronotum fine and rather sparse, interstices clearly alutaceous, that of the elytra appreciably stronger, interstices barely perceptibly alutaceous, that of the under side strong on the metasternum and very fine on the abdomen, interstices clearly alutaceous. Mouth parts and legs yellow, hind femora brown at base, abdomen brownish black in males; in females mouth parts and legs brown, tibiae and tarsi lighter than the femora. Prosternal carinae rather weak, fused just in front of the middle of the segment; femoral lines very broad, their external portions rather angular. Penis (pl. 5, fig. 131) almost as long as the paramera, rather narrow, the distal end blunt, the convex side with a toothlike tubercle located in front of the middle of the length. Female genitalia unknown.

Length of the body, 2.9-3.4 mm.; width, 2.2-2.5 mm.

Geographic distribution.—Localities as follows:

Michigan: White Fish Point, Lake Superior (NMC).
Illinois: Northern part (Peabody collection, now at Illinois Natural History Survey).
Minnesota: Little Winnebegosish (K. Cooper, NMC).

HYPERASPIS DISCONOTATA TROGLODYTES Mulsant

PLATE 1, FIGURE 31

Hyperaspis troglodytes MULSANT, 1853, p. 219.—CASEY, 1899, p. 127.
Hyperaspis discreta LECONTE, 1880, p. 187.

Smaller than the typical form, more broadly oval, not acuminate posteriorly, more strongly convex, maximum width reached at about the middle of the body length, as in most other species of *Hyperaspis*. Coloration of the head, pronotum, and the under side as in the typical *disconotata,* except that in *troglodytes* the yellow lateral margin of the pronotum is broader than the anterior margin in males. All the elytral spots more or less rounded; the humeral one rounded equilaterally triangular, the basal semicircular, the discal round or slightly longitudinally oval, the marginal semicircular, the apical rounded or transversely oval; the humeral and basal spots separated by at least half their own diameter. Penis as in the typical form but the distal end acuminate instead of blunt. The capsule of the spermatheca retort-shaped, basal portion moderately long, with a fairly large appendix.

Length of the body, 2.6-3.2 mm.; width, 1.9-2.3 mm.

Geographic distribution.—Localities as follows:

New Brunswick: Penobsquis (C. A. Frost, San Diego Museum collection).
Massachusetts: Sherborn, Rochester.

New York: Cascade, West Point.
Pennsylvania: Mount Alto.
Virginia: Skyland (Quirsfeld, SC).
Indiana: Orange County.
Iowa: Mount Pleasant, County No. 21 (SC).

Remarks.—The typical *disconotata* and *troglodytes* differ so strongly that at first sight there seems to be no question that they are distinct species. And yet, a complete series of intergrades between them has been observed. Individuals from Minnesota, Iowa, and Indiana are all intermediates, and assigning them to one or the other subspecies is a matter of taste. The typical *disconotata* is found on Lake Superior, the pure *troglodytes* on the Atlantic seaboard.

HYPERASPIS DISCONOTATA CANADENSIS, new subspecies

PLATE 1, FIGURE 34

Smaller, more oblong oval, and less convex than the typical *disconotata,* not acuminate posteriorly. The yellow vittae on the pronotum in the male unequal in width, the anterior being narrower than the lateral ones. The humeral, marginal, and apical spots of the elytra fused to form a narrow trisinuate marginal vitta slightly deflected from the margin in its posterior fifth; basal spot small, rounded, in one individual completely missing; discal spot very much elongated, at least four times longer than wide, in one individual fused with the basal spot to form a longitudinal vitta from the base to the apical fifth. Punctulation stronger than in the other two races of the species. Genitalia unknown.

Length of the body, 2.4-2.7 mm.; width, 1.7-1.9 mm.

Type.—In collection of F. T. Scott.

Paratype.—U.S.N.M. No. 54214.

Geographic distribution.—Locality as follows:

Alberta: Whitford Lake (six individuals including the type, O. Bryant, SC).

Remarks.—Although only six individuals of this form have been seen, considerable variation has been observed in the color pattern of the elytra. Further material is highly desirable.

HYPERASPIS TRIFURCATA Schaeffer

PLATE 3, FIGURE 101

Hyperaspis trifurcata SCHAEFFER, 1905, p. 143.

Broadly oval, somewhat obtusely rounded behind, moderately convex. In males head orange, in females black on the vertex, gradually becoming brown and brownish red on the clypeus. Pronotum in both sexes with orange stripes laterally, the width of the stripes tending to be greater in males. The ground color of the elytra varying from blood red, through brick red, to orange yellow, with a trident-shaped black design. The extent of the black pattern varying considerably: the red parts separating the prongs of the trident (corresponding to the discal spots) may become isolated to form spots, or may disappear giving rise to black elytra with undulated red vittae on all margins, interrupted by the black at the scutellum and at the apex. Punctulation of the pronotum dense and moderately strong, interstices alutaceous, that of the elytra less dense but about as strong as that of the pronotum, interstices polished. Mouth parts, legs, and margins of the abdomen brick red, femora darker, especially in females. Prosternal carinae well developed, femoral lines broadly and evenly arcuate. Penis (pl. 5, fig. 132) as long as the paramera, narrow and parallel sides basally, its distal end shaped like an eagle's beak. Female genitalia (pl. 6, fig. 158) resembling those of *disconotata.*

Length of the body, 2.4-3.0 mm.; width, 1.9-2.1 mm.

Geographic distribution.—Localities as follows:

Texas: Brownsville (on *Dactylopius confusus*), Falfurrias, San Diego, Kerrville, Hebbronville (on *Coccus cacti*), San Antonio, Seguin, Floresville, Tivoli, Corpus Christi, Los Borregos, Victoria, Alice, Sabinal, Fort Isabel, Uvalde (on *Dactylopius tomentosus*), Houston, College Station, and Sheffield, Pecos County.

Remarks.—There can be no doubt about *disconotata* and *trifurcata* being distinct species, although their distribution areas nowhere overlap, and therefore no opportunity to observe intermediates between them is available. On the other hand, in Mexico and Central America a number of "species" occur which are very likely to prove only subspecifically distinct from *trifurcata.* To this category belong in the first place Casey's species *durangoensis* and *disjunctus.* Judging from the types, these two are individual variants of the same form, and both are in all probability only races of *trifurcata.* Schaeffer himself (1905) suggested that *trifurcata* may be closley related to *guatemalensis* Gorham, but the latter species is not familiar to me.

XI. UNDULATA GROUP

Among the species of *Hyperaspis* inhabiting the United States this group is probably the most difficult one as far as distinguishing species is concerned. It consists of two subgroups, one centering around *undulata,* and the other around *quadrioculata;* the latter is the more difficult of the two. The elytral pattern includes the humeral, marginal, discal, and apical spots; the first, second, and fourth of these are frequently fused to form a marginal vitta. Male genitalia are characterized by penis and paramera being both long and slender, and by strong, though short, basal plates. In the female genitalia the capsule of the spermatheca is retort-shaped, gradually passing into the connecting duct.

HYPERASPIS UNDULATA (Say)

PLATE 2, FIGURE 56

Coccinella undulata SAY, 1824, p. 92.—MULSANT, 1850, p. 1049.—CASEY, 1899, p. 128.
Hyperaspis maculifera MELSHEIMER, 1847, p. 179.—LECONTE, 1880, p. 189.
Hyperaspis elegans MULSANT, 1850, p. 658.—LECONTE, 1880, p. 189.

Oval, slightly acuminate posteriorly, moderately convex. In males head yellow, pronotum with yellow lateral and anterior margins, the lateral yellow stripes being parallel-sided and rather narrow; in females head black, pronotum with only the lateral margins yellow. Elytra with a yellow sharply sinuate marginal vitta which is broadest in the apical region, and a longitudinally oval or rounded discal spot. In some individuals the marginal vitta resolved into humeral, marginal, and apical spots, the last being the largest. Punctulation of the pronotum dense and fine, interstices alutaceous, that of the elytra less dense but much stronger, interstices nonalutaceous, that of the under side dense and rather fine. Legs yellow, femora infuscate in females. Penis as long as, or longer than, the paramera, of a characteristic shape shown in plate 5, figure 126, its distal end broadly rounded. The proximal portion of the spermatheca short and broad, with a large appendix.

Length of the body, 2.3-2.7 mm.; width, 1.4-1.9 mm.

Geographic distribution.—From Canada to Virginia and west to Minnesota, Nebraska, Colorado, Utah, and Texas.

Remarks.—Individuals from the middle western States have the yellow pattern on the elytra more strongly developed than those from the Atlantic seaboard, and it may prove desirable to designate the western race as a separate subspecies.

HYPERASPIS OCTAVIA Casey

PLATE 1, FIGURE 7

Hyperaspis octavia CASEY, 1908, p. 419.

Very similar to *undulata,* but more broadly oval, rounded behind, a little more strongly convex. The yellow stripe on the lateral margin of the pronotum almost always broader anteriorly than posteriorly, and sometimes reduced to a yellow triangular spot in the anterior angles. Elytra with four yellow spots each: humeral spot triangular, marginal semicircular, apical transversely oval, and the discal one rounded or slightly longitudinally oval. Punctulation of the pronotum stronger than in *undulata.* Penis (pl. 5, fig. 128) large, longer and narrower than in *undulata,* truncate distally. Female genitalia as in *undulata.*

Length of the body, 2.3-2.8 mm.; width, 1.7-2.1 mm.

Geographic distribution.—Localities as follows:

Maine: Casco Bay (G. P. Engelhardt, SC).
New Hampshire: Claremont (SC).
Vermont: Mount Mansfield (NMC).
Massachusetts: Lexington, Sherborn, Cambridge, Framingham, Saugus.
New York: Rockaway Beach, West Point, Ithaca, Buffalo, top of Mount Whiteface.
Maryland: Patuxent River.
Virginia: Fortress Monroe, Fairfax.
Mississippi: Vicksburg (type, CC).
Michigan: Detroit, Golden Ledge.
Minnesota: Ramsey County, Battle Creek (University of Minnesota collection).

Remarks.—This species is close to *undulata,* and is superficially so similar to individuals of the latter species having the marginal vitta resolved into separate spots that it is misdetermined as *undulata* in most collections. The differences between the two species are numerous though small: body shape, punctulation of the pronotum, shape of the yellow vitta on the lateral margin of the pronotum and of the discal spot. Male genitalia are rather strikingly different. The geographic distributions of *octavia* and *undulata* are similar though not identical, and although the two species seem to occur side by side no intermediates are found.

HYPERASPIS PALUDICOLA Schwarz

PLATE 2, FIGURE 51

Hyperaspis paludicola SCHWARZ, 1878, p. 362.—LECONTE, 1880, p. 188.—CASEY, 1899, p. 128.

Small, elongate, little convex, sides of the pronotum feebly convergent anteriorly, sides of the elytra subparallel from the base to three-fourths of the length, thence rounded, and slightly acuminate at the apex. In males head yellow with a black bisinuate stripe on the vertex, pronotum with a rather broad yellow stripe on the lateral and a much narrower one on the anterior margins; in females head black, pronotum with only the lateral margins yellow. Elytra with a feebly undulate marginal vitta from the base nearly to the apex, and with a rather large longitudinally oval discal spot. Pronotum strongly alutaceous, punctulation sparse and very fine, elytral punctures strong and moderately dense, interstices feebly or not at all alutaceous, under side, except the sides of the metasternum, finely and sparsely punctulate. Legs yellow, abdomen or the whole under side piceous. Femoral lines broad, their external parts strongly angulate, not attaining either the posterior or the side margin of the first abdominal sternite; prosternal carinae very close, reaching forward to two-thirds of the length of the segment. Penis (pl. 5, fig. 127) long and narrow, the distal end rounded. The capsule of the spermatheca small, the proximal portion very small, with a large appendix.

Length of the body, 1.7-2.2 mm.; width, 1.1-1.4 mm.

Geographic distribution.—Localities as follows:

Florida: Tampa, Capron, Baldwin, Enterprise, Haw Creek, Ashby, Steinhatchee, Kissimmee (NMC, CC).
Alabama: Mobile (H. P. Loding, SC).
South Carolina: Sassafras Mountain (O. L. Cartwright, SC).
Virginia: Wingina (W. T. Davis collection).
?? Massachusetts: Provincetown (SC).

Remarks.—Individuals from States other than Florida are somewhat larger, and may represent a separate race. The finding of this species at Provincetown requires confirmation.

HYPERASPIS PUNCTATA Leconte

PLATE 2, FIGURE 50

Hyperaspis punctata LECONTE, 1880, p. 188.

Elongate, little convex, sides of the pronotum feebly convergent anteriorly, the sides of the elytra subparallel, the apical part obtusely rounded and not at all acuminate. Head yellow in males and black in females, pronotum in both sexes with yellow lateral and black anterior margins. Elytra with a strongly sinuate yellow marginal vitta extending from the base to slightly more than the middle of the length, a round discal spot located distinctly in front of the middle of the length, and a transversely oval apical spot. Punctulation of the pronotum moderately dense and strong, that of the elytra only slightly stronger, interstices very faintly or not at all alutaceous, that of the under side sparse and fine, except on the metasternum where it is strong. Legs yellow, under side varying from dark piceous to light brown. Femoral lines and prosternal carinae as in *paludicola,* but the former much narrower. Penis (pl. 5, fig. 129) very small, almost parallel-sided at base, asymmetry not strongly pronounced, the tip rounded. Female genitalia unknown.

Length of the body, 2.2-2.7 mm.; width, 1.3-1.7 mm.

Geographic distribution.—Localities as follows:

South Dakota: Belvidere (K. Cooper, NMC).
Texas: Belfrage, Gregory, Cotulla, Victoria, Brownsville.
New Mexico: Clovis (NMC).

HYPERASPIS FILIOLA Casey

PLATE 1, FIGURE 8

Hyperaspis filiola CASEY, 1908, p. 419.

Body shape resembling that of *punctata*. In the type (a female) head and pronotum black, elytra with a yellow marginal vitta extending from the base nearly to the apex, its internal outline only slightly undulate, and with a longitudinally oval discal spot the center of which lies behind the middle of the length of the elytron. Punctulation of elytra and the pronotum almost equally dense and strong, interstices not alutaceous, that of the under side much finer, except on the metasternum. Tibiae and tarsi brownish yellow, the rest of the under side dark piceous. Femoral lines as in *punctata*. Genitalia unknown.

Length of the body, 2.1 mm.; width, 1.2 mm.

Geographic distribution.—Locality as follows:

Arizona: Nogales (type, CC).

Remarks.—I have seen only the single type specimen of this species, which shows a curious mixture of the distinctive characters of *punctata* and *paludicola*. Further material is needed before the status of *filiola* can be determined.

HYPERASPIS QUADRIOCULATA QUADRIOCULATA (Motschulsky)

PLATE 2, FIGURE 57

Exochomus quadrioculata MOTSCHULSKY, 1845, p. 383.—MULSANT, 1850, p. 676.—LECONTE, 1880, p. 188.—CASEY, 1899, p. 128; 1908, p. 418.

Greatly variable in size, elongate oval, little convex. In males head yellow with a black bisinuate stripe on the vertex, in females head black. Pronotum in both sexes with a narrow yellow stripe on the lateral margins. Elytra with yellow suffused with brown discal and apical spots, and, in individuals intermediate between *quadrioculata quadrioculata* and *quadrioculata notatula,* with traces of humeral and marginal spots. The discal spot round or longitudinally oval, the apical one transversely oval. Punctulation of the pronotum very dense but fine, interstices very faintly alutaceous, that of the elytra a little less dense but much stronger, that of the abdomen sparse and fine, that of the sternum dense and very coarse. Under side black or dark piceous, tibiae, tarsi, and parts of femora yellow in males, fuscous in females. Prosternal carinae strongly developed, reaching close to the anterior margin, femoral lines large, their inner parts steep, middle parts subparallel to the posterior margin of the first sternite, outer parts more or less angular. Penis (pl. 5, fig. 130) long and narrow, gradually narrowing distally, truncate at the end; paramera long and slender. The proximal portion of the spermatheca elongate, with a large appendix.

Length of the body, 2.2-3.3 mm.; width, 1.2-2.3 mm.

Geographic distribution.—Localities as follows:

California: Mendocino County (San Diego Museum collection), Sonoma County, Santa Rosa, Lagunitas, Fairfax, Mill Valley, Martinez, Mount Diablo, Vine Hill, Alhambra Valley, Berkeley, Oakland, Piedmont, Alameda, San Francisco, San Pablo, Milbrae, Crystal Lake, Burlingame, Stanford University, Sunnyvale, Santa Clara, Niles, Pacific Grove, Carmel, Monterey, Adams Springs, Lake County, Davis, Yuba County, Sacramento, Lodi (reared from Baker's mealybug infesting grapes, F. T. Scott), Stockton, Tracy, Sequoia National Park, Potwisha.

HYPERASPIS QUADRIOCULATA NOTATULA Casey

PLATE 2, FIGURE 59

Hyperaspis notatula CASEY, 1899, p. 121; 1908, p. 418.

Differs from the typical *quadrioculata* by being somewhat more broadly oval, by having the yellow stripes on the lateral margins of the pronotum wider, and by having the spots on the elytra well defined and bright yellow in color. Humeral and marginal spots present, the former triangular in shape, sometimes reduced to a yellow streak, the latter semicircular. The discal spot larger than in *quadrioculata quadrioculata,* longitudinally oval, apical spot also larger, transverse; in a few individuals the discal spot obsolete, producing a superficial resemblance to *psyche*. Genitalia identical with those of the typical form.

Length of the body, 2.2-2.6 mm.; width, 1.4-1.9 mm.

Geographic distribution.—Localities as follows:

Nevada: Reno (type, CC).

California: Marin County, Sonoma County, San Joaquin County, Stockton, Laguna Mountains, Ahwahnee, South Fork Kings River, Sequoia National Park, Kaweah, Potwisha, Tulare, Visalia, Kern County, Pacific Grove, Monterey, Carmel, Pinnacles National Monument, Tassajara, Havilah, San Luis Obispo, Paso Robles, Santa Paula, Santa Barbara, Los Angeles, Pasadena, Mount Lowe, Mount Wilson, Sierra Madre, Bishop.

Arizona: Benson, Nogales (C. W. Leng collection).

Remarks.—Casey first thought *notatula* to be a relative of *lateralis,* but later has correctly recognized its similarity to *quadrioculata*. Indeed, although the extreme specimens of the two forms appear to be rather widely different, all the intermediates have been found (in San Joaquin Valley of California), and I consider the subspecific status of *notatula* established.

HYPERASPIS QUADRIOCULATA SCOTTI, new subspecies

PLATE 2, FIGURE 58

Pale markings on the head and the pronotum more strongly developed than in the typical *quadrioculata*, orange yellow in color. Elytra without the humeral spot, but with the other spots of the typical pattern very large, bright orange yellow in color, the marginal and discal ones broadly confluent. Genitalia identical with those of the typical form.

Length of body, 2.4-2.6 mm.; width, 1.6-1.8 mm.

Type.—In collection of F. T. Scott.

Paratype.—U.S.N.M. No. 54215.

Geographic distribution.—Localities as follows:

California: San Joaquin County (9 individuals including the type, F. T. Scott, SC), Lodi (3 individuals, reared from Baker's mealybug infesting grapes, SC, P. H. Timberlake collection), Stockton (one individual, E. P. Van Duzee, CASC).

Remarks.—This seems to be a narrowly localized race of *quadrioculata;* no intermediates between it and the typical form or the subspecies *notatula* have been found despite the fairly large number of individuals examined, which suggests that *scotti* differs from the other subspecies in a genetically simple way.

HYPERASPIS QUADRIOCULATA FIDELIS Casey

PLATE 1, FIGURE 9

Hyperaspis fidelis CASEY, 1908, p. 418.

More broadly oval than other races of *quadrioculata.* Coloration of the head and pronotum as in subspecies *notatula.* Elytra with a yellow marginal vitta extending from the base to two-thirds of the length, the internal outline of the vitta feebly sinuate, its maximum width attained at the level corresponding to the marginal spot of the basic pattern; discal spot large, longitudinally oval or wedge-shaped, apical spot large, transversely oval, sometimes showing a tendency toward confluence with the marginal vitta. Elytral markings bright yellow, clearly defined. Punctulation of the elytra and the pronotum dense and rather fine. Genitalia identical with those of the typical form.

Length of the body, 1.9-2.6 mm.; width, 1.4-1.8 mm.

Geographic distribution.—Localities as follows:

California: Pinnacles National Monument, Santa Paula, Los Angeles, Laguna Mountains, Pala, Escondido (beaten from lemons infested with mealybugs, F. T. Scott), Julian, Potrero, Warner Hot Springs, Cuyamaca, San Diego.

Remarks.—This is the southernmost known race of *quadrioculata,* which in the north merges into *quadrioculata notatula.*

HYPERASPIS TRIANGULUM Casey

Plate 1, Figure 10

Hyperaspis triangulum Casey, 1899, p. 123.

Oval, somewhat obtusely rounded behind, moderately convex. In males head yellow with a black bisinuate stripe on the vertex, in females black. Pronotum in both sexes with yellow stripes on the lateral margins which are about twice as long as wide and slightly narrower posteriorly than anteriorly, the anterior margin black. Elytra with yellow spots: a rounded or wedge-shaped discal one lying in front of the middle of the length, a semicircular or elongate marginal one located behind the middle, and a transversely oval apical one; in some individuals a yellow or brownish streak marks the position of the rudimentary humeral spot. Punctulation of the pronotum moderately dense and fine, that of the elytra almost as dense but appreciably stronger, that of the under side fine and sparse, except on the sternum where it is dense and coarse, interstices not alutaceous. Legs brownish yellow, femora infuscate in females, abdomen varying from light piceous to black. Prosternal carinae reaching to within a short distance of the anterior margin, femoral lines arcuate, their outer parts flatter than the inner ones, barely touching the posterior margin of the segment. Genitalia unknown.

Length of the body, 2.0-2.5 mm.; width, 1.6-1.9 mm.

Geographic distribution.—Localities as follows:

Texas: Finlay (J. O. Martin, CASC).

Arizona: Benson (type, CC).

California: Bear Flats, Julian (P. H. Timberlake collection), Cuyamaca, San Diego (San Diego Museum collection).

Remarks.—Casey considered *triangulum* to be a member of the *gemma* group; its very close relation to *quadrioculata* seems clear to me, even though the genitalia of *triangulum* are unknown. The California specimens of *triangulum* have larger elytral spots than Casey's type specimen which comes from Arizona. It is possible that the California population will have to be recognized as a separate subspecies, but more material is necessary to decide this point.

HYPERASPIS SPICULINOTA Fall

PLATE 2, FIGURE 60

Hyperaspis spiculinota FALL, 1901, p. 232.

Large, elongate oval, little convex, sides of the elytra subparallel for two-thirds of the length, very obtusely rounded behind. Head yellow with a black stripe on the vertex in males, black in females. Pronotum in both sexes with yellow stripes on lateral margins which are two or more times longer than wide, the anterior margin black. Elytra with a large, elongate, clearly wedge-shaped, yellow discal spot, a marginal spot that is from two to three times longer than wide, and a large transverse apical spot. Punctulation dense but rather fine, that of the elytra only slightly stronger than that of the pronotum, that of the under side sparse and fine, except on the sides of the metasternum where it is strong, interstices not alutaceous. Legs brownish yellow, femora and parts of the tibiae fuscous. Prosternal carinae reaching almost to the anterior margin, femoral lines angular externally, their middle parts running parallel to the posterior margin of the segment. Penis (pl. 5, fig. 133) long, rapidly narrowing distally and acuminate at the tip. The proximal portion of the spermatheca relatively shorter and broader than in *quadrioculata*.

Length of the body, 2.4-3.0 mm.; width, 1.7-2.1 mm.

Geographic distribution.—Localities as follows:

California: Pasadena, Monrovia, San Gabriel Canyon, Pomona, mountains near Claremont, Santa Barbara County (SC), Sequoia National Park (SC).

Remarks.—Although related to *quadrioculata, spiculinota* must be considered a separate species. It is endemic in southern California, and fairly common in the foothills of the Sierra Madre range. The single individual from Sequoia Park has the marginal spot reduced in size, semicircular instead of oblong.

HYPERASPIS SIMULATRIX, new species

Elongate oval, rather obtusely rounded behind. Head yellow with a broad black bisinuate stripe on the vertex in males, black in females. Pronotum in both sexes with yellow stripes on lateral margins, the stripes being two to three times longer than wide, the anterior margin black. Elytra with a yellow marginal vitta extending from the base to three-fifths of the length, the vitta narrow, undulate internally, attaining its maximum width in the region corresponding to the marginal spot; the discal spot longitudinally oval, in the type about three times longer than wide, in one of the cotypes only one and one-half times longer than wide; apical spot large, transversely oval. Punctulation of the pronotum dense but fine, that of the elytra only slightly sparser and stronger, that of the under side sparse and fine, except on the metasternum, interstices not alutaceous. Legs brownish yellow, femora and tibiae fuscous. Prosternal carinae well developed, reaching to three-quarters of the length of the segment, femoral lines broad, their middle parts parallel to the posterior margin, the outer parts angular. Penis (pl. 5, fig. 135) longer than the paramera, very long and slender, attaining its maximum width at about one-third of the length from the base, gradually narrowing distally. Paramera long and slender, basal plates short. Female genitalia unknown.

Length of the body, 2.2-2.5 mm.; width, 1.6-1.8 mm.

Type and three paratypes.—U.S.N.M. No. 54216.

Geographic distribution.—Localities as follows:

Idaho: Oakley (D. E. Fox, type, NMC), Wendell (Wind Vane trap, NMC), Hollister (D. E. Fox, NMC).
Montana: State record (H. K. Morrison, NMC).
Washington: Touchet (H. P. Lanchester, SC).

Remarks.—This species is related to *quadrioculata,* and its color pattern resembles that of *quadrioculata fidelis.* The striking difference in the structure of the male genitalia suggests however the two should be considered distinct species. It must also be noted that the geographic areas of *quadrioculata* and *simulatrix* are separated by a territory where no species of this group is known to occur; further exploration of this territory is evidently desirable.

XII. ANNEXA GROUP

Here belong five forms inhabiting the United States, which are closely related and represent relatively recent differentiation products of a single ancestral species. Nevertheless, some of them have become so different that they must now be classed as independent species. The elytral pattern consists of two longitudinal vittae, one of which is located on the outer margin and represents the fusion product of the numeral, marginal, and apical spots, and the other lies on the disk and must be regarded as a greatly elongated discal spot; the two vittae are sometimes fused, giving rise to pale elytra with a black design. Body shape elongate oval, feebly convex. Male genitalia are characterized by strongly elongate penis and paramera, and relatively short and weak basal plates. The capsule of the spermatheca retort-shaped, gradually passing into the connecting duct.

HYPERASPIS ANNEXA Leconte

PLATE 3, FIGURE 96

Hyperaspis annexa LECONTE, 1852, p. 133; 1880, p. 188.—CASEY, 1899, p. 128.

Oval, obtusely rounded behind, little convex, sides of the elytra feebly arcuate. In males head yellow with a black stripe on the vertex usually covered by the pronotum, pronotum with a broad vitta laterally which is as wide as, or wider than, long, and a broad vitta of the same color on the anterior margin, leaving only the central part of the pronotum black; in females head black, pronotum with yellow lateral margins which are as long as, or longer than, wide. Elytra with broad yellow marginal and discal vittae which, except very rarely, are broadly fused in the apical part; in some individuals the vittae tend to fuse at the basal margin as well, so that the elytra become yellow with a black vitta on the suture and another on the outer part of the disk. Pronotum densely and rather strongly, elytra less densely and somewhat more finely, punctulate, punctulation of the under side moderately dense and fine. Mouth parts and legs yellow, abdomen piceous, in females femora somewhat darker. Prosternal carinae rather close to each other but reaching far forward, femoral lines running for a distance parallel to the posterior margin of the segment, their outer parts angular. Penis (pl. 5, fig. 148) as long as the paramera, narrowing distally, and curved at the distal end. Basal part of the spermatheca elongate.

Length of the body, 2.2-2.7 mm.; width, 1.6-1.9 mm.

Geographic distribution.—Localities as follows:

California: Berkeley, Alameda, San Francisco, San Mateo County, Santa Paula, Ventura County, Santa Maria, Los Angeles, Pasadena, San Bernardino County, Colton, Bear Lake, San Diego (beaten from lemons infested with mealybugs, F. T. Scott), Playa del Rey, Isabella, Tulare County.
Idaho: Hansen (NMC).

Remarks.—The development of the pale color pattern on the elytra is greater in individuals from southern California than in those from the San Francisco Bay region. The only individual seen from Idaho, a female, may represent a very lightly pigmented specimen of *quadrivittata,* but it seems to be more like *annexa* than the former species.

HYPERASPIS QUADRIVITTATA QUADRIVITTATA Leconte

PLATE 3, FIGURE 98

Hyperaspis quadrivittata LECONTE, 1852, p. 133; 1880, p. 188.—CASEY, 1899, p. 128.

Elongate oval, obtusely rounded behind, very little convex, sides of the elytra feebly arcuate. In males head yellow anteriorly and black posteriorly, the black part forming a triangular process reaching in some individuals almost to the base of the labrum; in females head black. Pronotum in both sexes with a yellow lateral margin which is longer than wide. Elytra with yellow or yellowish-white marginal and discal vittae, both vittae narrow, the discal one extending from one-sixth to four-fifths of the length, its side subparallel, the marginal one extending from the humeral angles almost to the suture and the posterior end of the discal vitta, parallel-sided or slightly sinuate, somewhat deflected in the apical fourth from the margin, and in a few individuals almost fused with the discal one. Punctulation of the pronotum and the elytra uniformly dense and rather strong. Under side varying in color from piceous to black, mouth parts and legs yellow or fuscous. Penis (pl. 5, fig. 149) shorter than the paramera, less elongate than in *annexa,* and provided with a distinct triangular process located much nearer to the tip than to the base. Female genitalia as in *annexa.*

Length of the body, 2.0-2.7 mm.; width, 1.3-1.8 mm.

Geographic distribution.—Localities as follows:

Alberta: Medicine Hat (F. R. Carr, SC), Banff Springs (NMC).
Montana: Helena (NMC), Gallatin County (NMC).
Idaho: Parma, Buhl, Hollister.
Wyoming: Cheyenne, Yellowstone Park.
Iowa: Lake Okoboji (NMC).
Nebraska: Lincoln (NMC).
Colorado: Colorado Springs, Denver, Peaceful Valley.
New Mexico: Torrance County, Las Vegas (NMC).
Utah: Alta.
Arizona: Winslow (C. W. Leng collection).

HYPERASPIS QUADRIVITTATA variety TETRANEURA Casey

Hyperaspis tetraneura CASEY, 1908, p. 420.

Differs from the typical *quadrivittata* in having the yellow vittae on the elytra very narrow, the marginal one abbreviated, reaching only to two-thirds of the length of the margin. Genitalia identical with that of the typical form.

Geographic distribution.—Localities as follows:

Colorado: Boulder County (type, CC), Colorado Springs, Buena Vista (C. W. Leng collection).
New Mexico: Las Vegas (NMC).
Utah: Alta (NMC).

Remarks.—This appears to be a geographically localized color form of *quadrivittata.* I find no difference between them in the convexity of the body and the shape of the femoral line, as alleged by Casey (1908).

HYPERASPIS OREGONA, new species

PLATE 3, FIGURE 99

Oval, little convex, less obtusely rounded behind than the preceding species. In males head yellow with a broad undulate black stripe on the vertex, black in females. Pronotum in either sex with yellow lateral margins, the yellow areas being much longer than wide, with or without a very narrow yellow stripe on the anterior margin in males. Elytra with a yellow marginal vitta extending from the humeral angles to two-thirds of the length of the margin, usually broader in its anterior and posterior than in its middle part, a small transversely oval apical spot usually well separated from the end of the marginal vitta, and a yellow discal vitta extending from one-third to two-thirds of the length of the elytron, usually broader in its anterior than in its posterior half. Pronotum densely and finely, elytra less densely but more strongly, punctulate, interstices not alutaceous, under-side punctulation fairly sparse. Mouth parts and legs brownish yellow, femora infuscate, especially in females. Prosternal carinae and femoral lines as in *annexa*. Genitalia of both sexes resembling those of *annexa*, except that the penis (pl. 5, fig. 147) is more elongate and more uniformly broad.

Length of the body, 2.1-2.5 mm.; width, 1.5-1.7 mm.

Type.—In collection of F. T. Scott.

Four paratypes.—U.S.N.M. No. 54217.

Geographic distribution.—Localities as follows:

Oregon: Harney County (E. B. Leach, 2 ♂♂ including the type, SC), Harper (H. P. Lanchester, SC).

Washington: Walla Walla (H. P. Lanchester, SC), Wawawai (H. P. Lanchester, SC), Toppenish (D. Dunavan, SC).

Idaho: Craters of the Moon (D. J. and J. N. Knull, SC), Hollister (Wind Vane trap, NMC), Centerville (J. L. Webb, NMC).

Wyoming: Yellowstone Park (NMC).

Remarks.—This species is in a way intermediate between *annexa* and *quadrivittata*, and may conceivably, though not probably, prove to be a race of the former species.

HYPERASPIS OREGONA BOREALIS, new subspecies

PLATE 1, FIGURE 33

Differs from the typical form by a somewhat more elongate form of the body, and by having the elytra black with a yellow streak at three-quarters of the length of the elytron, located close to one-third of the width from the suture. This streak undoubtedly represents a remnant of the discal vitta of the type form. The yellow lateral margin on the pronotum somewhat narrower than in the type form, and in one individual nubilate. Genitalia unknown.

Length of the body, 2.4-2.6 mm.; width, 1.6-1.7 mm.

Type.—In collection of F. T. Scott.

Paratype.—U.S.N.M. No. 54218.

Geographic distribution.—Localities as follows:

Washington: Lake Cle Elum (H. P. Lanchester, 1 ♂, type, SC).
British Columbia: Vancouver (H. B. Leach, 1 ♀, SC).

HYPERASPIS BRUNNESCENS, new species

PLATE 3, FIGURE 97

Oval, somewhat obtusely rounded behind, subdepressed. In males head dull brownish yellow becoming darker toward the vertex, in females uniform dark brown. Pronotum more flattened and relatively longer than in related species, variable in color: in the type (♂) dull yellow with hazy infuscate areas on either side of the scutellum, or more or less evenly brownish yellow (♂, ♀), or dark brown becoming paler toward the lateral and the anterior margins (♀). Elytra brownish black with dull yellow vittae of the same type as in *quadrivittata* but somewhat broader, the marginal one more sinuate, the discal one shorter, and both with rather indistinct boundaries. Punctulation of the pronotum dense and fine, that of the elytra less dense but distinctly stronger, interstices in both cases clearly alutaceous, especially on the pronotum. Under side piceous brown, mouth parts, prosternum except on the middle, and legs fuscous yellow, mesosternum, metasternum, and abdomen darker at the middle than on the sides. Prosternal carinae close but reaching far forward, femoral lines in their middle parts running parallel to the hind margin of the segment, strongly angular externally. Male genitalia unknown, female ones like in *annexa*.

Length of the body, 2.3-2.5 mm.; width, 1.6-1.8 mm.

Type and three paratypes.—U.S.N.M. No. 54219.

Geographic distribution.—Localities as follows:

Illinois: State record (1 ♂, type, NMC), northern Illinois 3 ♂♂, 6 ♀♀ (NMC, C. W. Leng collection, Illinois Natural History Survey collection), Edgebrook (2 ♂♂, 3 ♀♀, CASC).

Remarks.—Despite being closely related to *quadrivittata, brunnescens* should, I believe, be considered a separate species. It has a strongly alutaceous surface of the elytra—a character not indicated in any of its relatives.

XIII. MOERENS GROUP

This group, containing two closely related species or races, differs from other representatives of *Hyperaspis* inhabiting the United States in having the tarsal claws simple, i.e., devoid of the tooth at the base (pl. 6, fig. 168). For this reason it has been made into a separate genus, *Oxynychus* Leconte. In my opinion, this genus is superfluous. In the first place, the type of the genus, *Oxynychus moerens* Leconte, is evidently closely related to the *annexa* group of *Hyperaspis*. Secondly, the Old World species of *Oxynychus* (*erytrocephalus* Fabr., *alexandrae* Weise) are closer to the *gemma* group of *Hyperaspis* than they are to the *moerens* group. In other words, the simple claws seemingly have arisen independently in otherwise not closely related sections of *Hyperaspis,* and hence *Oxynychus* as now constituted does not represent a natural group. I propose to treat *Oxynychus* Leconte as a synonym of *Hyperaspis* Redtenbacher.

HYPERASPIS MOERENS (Leconte)

PLATE 3, FIGURE 100

Oxynychus moerens LECONTE, *in* Agassiz, 1850, p. 238.—MULSANT, 1850, p. 694.—LECONTE, 1880, p. 188.—CASEY, 1899, p. 128.
Oxynychus consimilis LECONTE, 1852, p. 134; 1880, p. 189.

Elliptical, pronotum longer in relation to its width than in other species of *Hyperaspis,* elytra broader than the pronotum, evenly arcuate, subdepressed. In males head yellow on the clypeus and black on the vertex, the black part forming a triangular projection at the middle, pronotum with narrow nubilate yellow vittae on lateral margins which are broader anteriorly than posteriorly; in females head black, pronotum with suffused yellow vittae laterally. Elytra black or brownish black with suffused yellow remnants of a marginal vitta which may be broken up into streaks representing the humeral, marginal, and apical spots, and with a suffused yellow discal vitta of varying length, sometimes reduced to a streak at three-quarters of the length of the elytron. Punctulation of the pronotum and the elytra equally dense and strong, interstices not alutaceous. Under side dark piceous, mouth parts, legs, and margins of the abdomen yellowish brown. Prosternal carinae close but almost reaching the anterior margin, femoral lines running for a distance parallel to the posterior margin of the first abdominal sternite, their outer parts rather angular. The middle of the first abdominal sternite with very coarse punctures. Male genitalia unknown. The capsule of the spermatheca rounded, but the connecting duct becoming broader as it approaches the capsule.

Length of the body, 2.3-2.6 mm.; width, 1.5-1.7 mm.

Geographic distribution.—Localities as follows:

Michigan: Lake Superior (Leconte's type, not examined by the present writer).
Montana: Bear Paw Mountains (NMC).
Wyoming: Yellowstone Park (NMC).

Remarks.—The color scheme in this species is evidently similar to that in species of *annexa group.* The above-described *Hyperaspis oregona borealis* may be mistaken for *moerens,* but the two are easily distinguishable by their body shapes.

HYPERASPIS SIMULANS Casey

Hyperaspis simulans CASEY, 1899, p. 128.

Very similar to the preceding species. Elytra a little more obtusely rounded behind, making the body shape less evenly elliptical. Punctulation of the pronotum somewhat denser than that of the elytra. Elytra black or dark piceous, with or without a suffused yellowish streak marking the location of the humeral spot. Genitalia unknown.

Length of the body, 2.1-2.7 mm.; width, 1.4-1.8 mm.

Geographic distribution.—Localities as follows:

Arizona: Nogales (type, CC), Palmerlee (NMC), Williams (NMC), Huachuca Mountains (SC).

Remarks.—*H. simulans* and *moerens* are probably only subspecifically distinct, but more material than now available is needed to establish their status.

XIV. SPECIES HAVING NO CLOSE RELATIVES IN THE FAUNA OF THE UNITED STATES

HYPERASPIS BOLTERI Leconte

PLATE 3, FIGURE 95

Hyperaspis bolteri LECONTE, 1880, p. 186.—CASEY, 1899, p. 121.

Oval, little convex, elytra narrower at humeral angles than further caudad, acuminate posteriorly, pronotum considerably longer at the middle than on lateral margins, the distance between its anterior angles being decidedly smaller than between its posterior ones. In males head ochraceous, dark on the vertex, pronotum with rather narrow ochraceous vittae laterally, the anterior margin very narrowly yellowish; in females head and pronotum black. Elytra with a very broad ochraceous orange marginal vitta sharply expanded at three-fifths of the length to form a discal spot broadly fused with the main body of the vitta, which almost reaches the apical part of the suture. Pronotum strongly alutaceous, punctulation almost obsolete, elytra feebly alutaceous, punctulation dense and moderately strong, punctulation of the under side very dense and coarse on sides of the metasternum, fine elsewhere, on the abdomen almost obsolete. Mouth parts, tibiae and tarsi brownish red, femora dark fuscous. Prosternal carinae almost reaching the anterior margin, femoral lines flat, clearly not reaching the posterior margin of the first abdominal sternite, their outer parts angular. Penis (pl. 5, fig. 134) about as long as the paramera, long and narrow, nearly parallel-sided basally, with an excision on one side and a tubercle on the other in the distal part. The capsule of the spermatheca retort-shaped, the basal portion large, strongly chitinized, with a long appendix.

Length of the body, 3.0-3.1 mm.; width, 2.1 mm.

Geographic distribution.—Localities as follows:

Illinois: Northern part of the State (SC).
Kansas: State record (NMC).

Remarks.—This rare species seems to have no close relatives among the species of *Hyperaspis* known to the writer. It might be placed in the neighborhood of the *taeniata group,* but this is no more than a guess.

HYPERASPIS JOVIALIS Fall

PLATE 2, FIGURE 69

Hyperaspis jovialis FALL, 1925, p. 311.

Broadly oval, rather obtusely rounded behind, moderately convex. In the male head and pronotum whitish yellow, the latter with a black trident pattern in front of the scutellum, the middle prong of the trident being much narrower than the outer ones; in females head and pronotum black, the latter with a whitish-yellow vitta laterally, the length of which is distinctly greater than the width, and the inner boundary of which is uneven. Coloration of the elytra variable; it consists of a cream-colored vitta extending from one-eighth or one-fourth of the length to one-eighth before the apex; the vitta may be broken into a very large discal and a relatively small apical spot; or it may become expanded so that elytra become pale with black margins and a black spot in the posterior third. Punctulation of the pronotum and the elytra moderately dense but very fine, interstices highly polished, shining, that of the under side dense but fine, except on the sides of the metasternum where it is coarse. In the male mouth parts, front and middle legs and tibiae and tarsi of hind legs yellow, in females tibiae and tarsi of all legs brownish yellow. Prosternal carinae well developed, femoral lines arcuate, their middle parts running parallel to the posterior margin, their outer parts angular and leveled up before reaching the margins of the segment. Genitalia unknown.

Length of the body, 2.4-2.7 mm.; width, 1.7-2.0 mm.

Geographic distribution.—Localities as follows:

California: Kern County, Havilah (type, not examined by the writer), Tulare County (F. T. Scott, SC), Los Angeles County, Big Pines (Th. Dobzhansky), San Bernardino County (F. T. Scott, SC).

Remarks.—This species is superficially similar to *H. leachi,* and hence to the *binotata* group. This is, however, too tenuous a basis to assign to *jovialis* a definite place at present. The variability of the elytral pattern in *jovialis* is remarkable, and may conceivably indicate the presence of two or more geographic races, but here again further material is needed before a decision is reached.

HYPERASPIS CALIFORNICA, new species

PLATE 2, FIGURE 72

Broadly oval, little convex, sides of the elytra feebly arcuate, obtusely rounded behind, head and pronotum relatively short and very broad. In males head yellow, pronotum with light yellow vittae on the lateral and anterior margins, the former about twice as long as wide, sometimes produced for a short distance along the basal margin, the vitta on the anterior margin half as wide as the lateral ones; in females head black, pronotum with lateral yellow vittae only. Elytra with orange-red discal and apical spots; the former rounded or longitudinally oval, located closer to the external margin than to the suture, rather small in the type and much enlarged in one of the cotypes, the apical one transversely oval. Punctulation of the pronotum sparse and obsolescent, that of the elytra slightly denser and very fine, that of the under side dense and fine, coarser on the metasternum. Mouth parts and legs yellow, hind femora fuscous. Prosternal carinae abbreviated, reaching forward to a little more than half of the length of the segment; femoral lines strongly arcuate internally, their external parts on the contrary very flat, forming a very sharp angle with the posterior margin of the first abdominal sternite. Genitalia unknown.

Length of the body, 2.8-3.1 mm.; width, 2.0-2.4 mm.

Type and paratype.—U.S.N.M. No. 54220.

Geographic distribution.—Localities as follows:

California: Mount San Jacinto (Th. Dobzhansky, type, now at NMC); Los Angeles County (Coquillet collection, now in NMC); Claremont (SC); Forest Home, San Bernardino County (E. P. Van Dyke, 3 individuals, CASC).

Remarks.—This species may prove to be an aberrant member of the *binotata* group, but it is less convex than any of its presumed relatives, and the shape of its prosternal carinae and femoral lines is unusual. F. T. Scott's collection contains two individuals (one from Huachuca Mountains, Ariz., D. J. and J. N. Knull, collectors, and the other from Globe, Ariz., collector not stated) which have black elytra and a somewhat stronger punctulation than the California specimens of *californica,* but which otherwise may belong to a separate race of the same species. A formal description of this race is better postponed till more material is available.

HYPERASPIS ESCLAVIUM, new species

Plate 2, Figure 64

Broadly oval, rather strongly convex. In males head yellow, pronotum with subquadrate yellow spots laterally and a yellow anterior margin; in females head black, pronotum with the lateral pale spots only. Elytra with yellow basal, discal, and two apical spots: an inner and an outer one; basal spot large, rounded triangular, with a blunt process toward the suture which it does not reach; discal spot obliquely oval, fused with the arrowhead-shaped inner apical one, the two together forming a spearlike figure; the outer apical the smallest in size, wedge-shaped, the sharp end of the wedge lying near the outer margin and pointed forward; in one of the cotypes the basal spot fused with the discal and inner apical ones to form an arcuate discal vitta. Punctulation of the pronotum and the elytra uniformly dense and strong, that of the under side less strong except on the sides of the metasternum. Mouth parts and legs yellow, the abdomen or its outer edges piceous, in males mesosternal epimera yellowish white. Prosternal carinae long, almost reaching the anterior margin of the segment; femoral lines very broad, their middle parts running for a considerable distance parallel to the posterior margin of the first abdominal sternite, their outer parts strongly angular. Genitalia unknown.

Length of the body, 2.2-2.6 mm.; width, 1.7-2.0 mm.

Type and three paratypes.—U.S.N.M. No. 54221.

Geographic distribution.—Locality as follows:

Mississippi: Biloxi (2 ♂♂, including the type, and 2 ♀♀, C. C. Dean, NMC).

Remarks.—This species has no relatives in the United States, but is probably rather closely related to the common and widespread in the tropical America *H. compedita* Mulsant. I have seen specimens of the latter from Mexico, Morelos, and Mitla (NMC).

HYPERASPIS NUBILATA Casey

Hyperaspis nubilatus CASEY, 1924, p. 166.
Hyperaspis asphaltina CASEY, 1924, p. 166.

Elongate, little convex; head large, relatively short and broad, eyes prominent; pronotum almost as wide between the anterior as between the posterior angles, the sides evenly rounded, the anterior margin straight; sides of the elytra subparallel from the humeral angles to five-sixths of the length, truncate and obtusely rounded behind, the tergite of the last abdominal segment exposed in some individuals, including the type of *asphaltina*. Head brownish black, the clypeus paler in some individuals, pronotum and elytra piceous black, the former sometimes (in ♂♂?) with nubilate pale stripes laterally, the sides of the elytra also with rudiments of nubilous pale marginal vitta. Punctulation of the pronotum rather dense and fine, interstices feebly alutaceous, that of the elytra as dense but stronger, the punctures on the anterior portion tending to form irregular rows, that of the under side dense and rather strong. Under side brown, mesosternum and metasternum piceous black, legs testaceous with infuscate hind femora. Genitalia unknown.

Length of the body, 1.7-2.2 mm.; width, 1.2-1.4 mm.

Geographic distribution.—Localities as follows:

North Carolina: Southern Pines (Manee, types and paratypes, CC).
Georgia: Chester (F. Knab collection, now in NMC).

Remarks.—The two species, *nubilata* and *asphaltina,* described by Casey represent in my opinion individual variants of the same form, which is the most peculiar one among the species of *Hyperaspis* known to me, and may in fact deserve being segregated as a separate subgenus or even a genus. I have examined the characters by which the existing genera of *Hyperaspini* are at present separated, and found that from this standpoint *nubilata* must provisionally be classed as a very aberrant *Hyperaspis.*

XV. DOUBTFUL OR INADEQUATELY DESCRIBED SPECIES

The present writer has been unable to identify some of the species described as belonging to the genus *Hyperaspis* among the materials available to him. Some of these species are probably valid and could be with a reasonable certainty identified from their original descriptions, while others, especially those of older authors, are almost beyond doubt synonyms of species otherwise well known. The later category is of interest chiefly in so far as they may cause involved nomenclatorial changes. Since no opportunity of examining the types of these species is available, their original descriptions are quoted below, with such comment as seems reasonable.

HYPERASPIS ANNULARIS Boheman

Hyperaspis annularis Boheman, 1859, p. 205.

The original description is in Latin; the following is a translation of a part of it.

Pronotum . . . . black, shining . . . . with the anterior margin narrowly, and the lateral one no more broadly testaceous yellow, the yellow part being continued on either side along the base. Elytra . . . . black, shining, with a testaceous yellow lateral margin and a large spot on the posterior part, united in front of the apex with that of the opposite side, this spot including a rather large round black spot. Abdomen with testaceous yellow margins. Legs testaceous yellow.

Geographic distribution.—California.

Remarks.—The elytral color pattern indicated by the above description is very unusual indeed for a species of *Hyperaspis;* unless the genus is misidentified, it must be a very distinctive form.

HYPERASPIS HORNI Crotch

Hyperaspis horni Crotch, 1873, p. 371.

Female—Closely related to *H. undulata,* but smaller, shorter and rounder, more finely punctate, elytra with a straight margin for two-thirds, a discoidal spot (much nearer the base than in *undulata*), and a triangular sub-apical spot yellow. L. .8 inch. California (Horn).

Remarks.—Leconte (1880, p. 189) believed *horni* Crotch to be a synonym of *lateralis* Mulsant, whereas Casey has at first equated *horni* with *quadrioculata* Motschulsky (1899, p. 128), but later (1908, p. 418) withdrew this opinion. To me, the description of *horni* suggests most *bensonica* Casey, but as the type of the former is unknown, this guess is no safer than the previous ones.

HYPERASPIS NIGROPENNIS Blatchley

Hyperaspis nigropennis Blatchley, 1924, p. 167.

Broadly oval, strongly convex. Black, shining; side margins of thorax above and beneath rather broadly reddish yellow; elytra without spots; front femora except under side, tips of middle and hind ones and all the tibiae and tarsi reddish brown. Entire upper surface finely evenly, rather sparsely punctate. Elytra widest at middle, their tips broadly and bluntly rounded. L. 3 mm. Dunedin, March 28.

HYPERASPIS PLUTO Fall

Hyperaspis pluto Fall, 1925, p. 311.

Subrotundate, rather strongly convex, entirely black above except for the side margins of the prothorax which are very narrowly reddish yellow. Upper surface polished throughout, with barely perceptible alutaceous sculpture in the clypeal region. Punctation fine, sparse, and nearly uniform throughout, the punctures separated on the average by about three times their own diameters; a little closer narrowly along the front and the side margins of the thorax. Body beneath black, tarsi and inner face of tibiae more or less rufous; metasternum closely and rather coarsely punctate, ventral segments less densely and more finely punctured, especially at middle. L. 3.75 mm.; W. 3 mm.

Geographic distribution.—Locality as follows:

California: San Bernardino Mountains.

HYPERASPIS SUBSIGNATA Crotch

Hyperaspis subsignata Crotch, 1874, p. 226.

♂ Hemispherical, ochreous yellow clouded with reddish, clearly shining, punctulate; head yellow, thorax reddish, sides broadly and anterior margin narrowly ochreous, the latter produced posteriorly in the middle; elytra ochreous; the suture and a small spot on the callus reddish. L. $\frac{3}{4}$-1 lin. Mexico, Campeachy, Texas (Deyrolle). ♀ Head with vertex reddish, thorax with sides only pale, size larger, punctuation finer.

HYPERASPIS TRISTIS (Leconte)

Oxynychus tristis Leconte, 1880, p. 188.

Claws slender, not dilated at base, body elliptical, less convex than usual; abdomen finely sparsely punctulate. . . . . Elytra with a small rounded spot near the tip, and some faint traces of marginal spots; prothorax with narrow yellow side margin; ♂ front yellow; 2 mm.; Colorado (Hardy).

XVI. SPECIES DESCRIBED IN HYPERASPIS BUT HERE REMOVED TO OTHER GENERA

HYPERASPIS CAROLINA Casey

Hyperaspis carolina Casey, 1924, p. 164.

Examination of the type of this species (Casey's collection, NMC) shows that it belongs to the genus *Brachyacantha* and represents an apparently diminutive specimen of *B. flavifrons* Mulsant.

HYPERASPIS FLORIDANA Mulsant

Hyperaspis floridana Mulsant, 1850, p. 1040.

Crotch (1873, p. 379) believes this to be a species of *Scymnus,* namely, *S. amabilis* Leconte, and his opinion is borne out by the description.

HYPERASPIS SEXUALIS Casey

Hyperaspis sexualis Casey, 1924, p. 167.

Examination of the type shows that this form belongs to the genus *Scymnus,* the species of which I cannot identify.

HYPERASPIS FALLI Nunenmacher

Hyperaspis falli Nunenmacher, 1912, p. 450.

HYPERASPIS PLORIBUNDA Nunenmacher

Hyperaspis ploribunda Nunenmacher, 1911, p. 74.

HYPERASPIS WOLCOTTI Nunenmacher

Hyperaspis wolcotti Nunenmacher, 1911, p. 73.

The above three species, although described as belonging to *Hyperaspis,* are apparently members of the genus *Hyperaspidius* Crotch. Nunenmacher himself in his description of *ploribunda* compares it with *Hyperaspidius arcuatus* Leconte, and indicates that *falli* is intermediate between *ploribunda* and *simulans* (the latter being, however, a species of *Hyperaspis*). As to *wolcotti,* its description leaves little doubt that a species of *Hyperaspidius* is here involved.

EXPLANATION OF PLATES

All the sketches in these plates represent camera lucida drawings made at magnifications stated below. In so far as possible, the type specimens of various forms have been used, but occasionally the specimens selected proved to be not the most characteristic for a given species or race; thus, in some instances the specimens represented are larger or smaller than the average in size. The majority of individuals represented are males.

Plate 1

Fig. 1. *Hyperaspis conspirans* Casey (type).
Fig. 2. *H. fastidiosa fastidiosa* Casey (type).
Fig. 3. *H. bensonica bensonica* Casey (type).
Fig. 4. *H. gemma* Casey (type).
Fig. 5. *H. pratensis medialis* Casey (type).
Fig. 6. *H. pratensis aemulator* Casey (type).
Fig. 7. *H. octavia* Casey (type).
Fig. 8. *H. filiola* Casey (type).
Fig. 9. *H. quadrioculata fidelis* Casey (type).
Fig. 10. *H. triangulum* Casey (type, elytra slightly divergent).
Fig. 11. *H. effeta* Casey (type).
Fig. 12. *H. tuckeri* Casey (type).
Fig. 13. *H. elliptica* Casey (type).
Fig. 14. *H. uniformis* Casey (type).

FIG. 15. *H. postica* Leconte.
FIG. 16. *H. subdepressa* Casey (type).
FIG. 17. *H. proba weisei* Schaeffer (cotype).
FIG. 18. *H. oculaticauda* Casey (type).
FIG. 19. *H. protensa* Casey (type).
FIG. 20. *Hyperaspis taeniata taeniata* Leconte (female).
FIG. 21. *H. taeniata perpallida,* new variety (type, male).
FIG. 22. 3-mm. scale applicable to figs. 1-19.
FIG. 23. *Hyperaspis taeniata pallescens,* new variety (type, female).
FIG. 24. *H. taeniata significans* Casey (male).
FIG. 25. *H. taeniata rufescens,* new subspecies (type, male).
FIG. 26. *H. taeniata cruenta* Leconte (male).
FIG. 27. *H. taeniata cruentoides,* new subspecies (type, male).
FIG. 28. *H. pleuralis* Casey (male).
FIG. 29. *H. osculans* Leconte (male).
FIG. 30. *H. taeniata binaria* Casey (female).
FIG. 31. *H. disconotata troglodytes* Mulsant.
FIG. 32. *H. leachi* Nunenmacher.
FIG. 33. *H. oregona borealis,* new subspecies (type, male).
FIG. 34. *H. disconotata canadensis,* new subspecies (type, male).
FIG. 35. *H. proba proba* (Say).
FIG. 36. *H. oculifera* Casey (male).
FIG. 37. *H. revocans occidentalis,* new subspecies (type, male).
FIG. 38. 3-mm. scale applicable to figs. 20-37.

PLATE 2

FIG. 39. *Hyperaspis lateralis lateralis* Mulsant (male).
FIG. 40. *H. lateralis montanica* Casey (male).
FIG. 41. *H. lateralis flammula* Nunenmacher (male).
FIG. 42. *H. lateralis nigrocauda,* new subspecies (female, type).
FIG. 43. *H. lateralis omissa* Casey (male).
FIG. 44. *H. lateralis wellmani* Nunenmacher (male).
FIG. 45. *H. excelsa* Fall.
FIG. 46. *H. taedata* Leconte.
FIG. 47. *H. pratensis pratensis* Leconte (male).
FIG. 48. *H. fastidiosa septentrionis,* new subspecies (type).
FIG. 49. *H. globula* Casey.
FIG. 50. *H. punctata* Leconte.
FIG. 51. *H. paludicola* Schwarz.
FIG. 52. *H. besonica disrupta,* new subspecies.
FIG. 53. *H. octonotata* Casey.
FIG. 54. *H. fastidiosa* Casey (male with large spots).
FIG. 55. *H. chapini,* new species (type).
FIG. 56. *H. undulata* (Say) (male).
FIG. 57. *H. quadrioculata quadrioculata* (Motschulsky).
FIG. 58. *H. quadrioculata scotti,* new subspecies (type).
FIG. 59. *H. quadrioculata notatula* Casey.
FIG. 60. *H. spiculinota* Fall.
FIG. 61. *H. biornata arizonica,* new subspecies.
FIG. 62. *H. levrati* (Mulsant).

FIG. 63. *H. revocans revocans* Casey.
FIG. 64. *H. esclavium,* new species (type, male).
FIG. 65. *H. disconotata disconotata* Mulsant.
FIG. 66. *H. rotunda* Casey.
FIG. 67. *H. connectens* (Thunberg).
FIG. 68. 3-mm. scale, applicable to figs. 39-72.
FIG. 69. *H. jovialis* Fall (male).
FIG. 70. *H. lugubris* (Randall).
FIG. 71. *H. biornata biornata* Nunenmacher.
FIG. 72. *H. californica,* new species (type, male, elytra divergent).

PLATE 3

FIG. 73. *Hyperaspis binotata* (Say) (male).
FIG. 74. *H. centralis wickhami* Casey (male).
FIG. 75. *H. bicentralis bicentralis* Casey.
FIG. 76. *H. lewisi* Crotch (male).
FIG. 77. *H. haematosticta* Fall.
FIG. 78. *H. signata* (Olivier).
FIG. 79. *H. pinorum* Casey (male).
FIG. 80. *H. gemina* Leconte (female).
FIG. 81. *H. rivularis,* new species (type, male).
FIG. 82. *H. centralis plagiata,* new subspecies (type, male).
FIG. 83. 3-mm. scale applicable to figs. 73-84.
FIG. 84. *H. bigeminata* (Randall) (male).
FIG. 85. *H. nunenmacheri* Casey.
FIG. 86. *H. fimbriolata fimbriolata* Melsheimer.
FIG. 87. *H. fimbriolata inflexa* Casey.
FIG. 88. *H. psyche* Casey (an individual more elongate than the mode).
FIG. 89. *H. fimbriolata serena* Casey.
FIG. 90. *H. cincta* Leconte.
FIG. 91. *H. fimbriolata atlantica,* new subspecies (type).
FIG. 92. *H. sanctae-ritae,* new species (type, male).
FIG. 93. *H. dissoluta dissoluta* Crotch.
FIG. 94. *H. dissoluta coloradana* Casey.
FIG. 95. *H. bolteri* Leconte.
FIG. 96. *H. annexa* Leconte (male).
FIG. 97. *H. brunnescens,* new species (type, male).
FIG. 98. *H. quadrivittata quadrivittata* Leconte (male).
FIG. 99. *H. oregona,* new species (type, male).
FIG. 100. *H. moerens* (Leconte) (male).
FIG. 101. *H. trifurcata* Schaeffer.
FIG. 102. 3-mm. scale applicable to figs. 85-101.

PLATE 4

FIG. 103. 0.5-mm. scale applicable to figs. 104 and 106.
FIG. 104. Reproductive organs of a *Hyperaspis lateralis* male. AG, accessory gland; BP, basal plates; DE, ductus ejaculatorius; P, penis; PA, paramera; S, sipho; SV, seminal vesicles; T, testes; TR, trabes; VD, vas deferens.
FIG. 105. Penis, basal plates, and paramera of *Hyperaspis fastidiosa fastidiosa* Casey. Significance of letters as in fig. 104.

FIG. 106. Reproductive organs of a *Hyperaspis lateralis* female. BC, bursa copulatrix; GR, accessory gland of the spermatheca; OD, oviduct; OV, ovaries; RS, spermatheca; 9ST, ninth sternite; 10T, tenth tergite.
FIG. 107. Outline of the penis of *H. conspirans* Casey.
FIG. 108. Outline of the penis of *H. gemma* Casey.
FIG. 109. Outline of the penis of *H. pratensis pratensis* Leconte.
FIG. 110. Outline of the penis of *H. chapini,* new species.
FIG. 111. Outline of the penis of *H. levrati* (Mulsant).
FIG. 112. Outline of the penis of *H. oculifera* Casey.
FIG. 113. Outline of the penis of *H. rotunda* Casey.
FIG. 114. Outline of the penis of *H. excelsa* Fall.
FIG. 115. Penis, basal plates, and paramera of *H. revocans revocans* Casey.
FIG. 116. Penis, basal plates, and paramera of *H. connectens* (Thunberg).
FIG. 117. Outline of the penis of *H. bicentralis bicentralis* Casey.
FIG. 118. Outline of the penis of *H. signata* (Olivier).
FIG. 119. Outline of the penis of *H. bigeminata* (Randall).
FIG. 120. Penis, basal plates, and paramera of *H. lateralis lateralis* Mulsant.
FIG. 121. Outline of the penis of *H. centralis wickhami* Casey.
FIG. 122. Outline of the penis of *H. octonotata* Casey.
FIG. 123. Outline of the penis of *H. binotata* (Say).
FIG. 124. Outline of the penis of *H. haematosticta* Fall.
FIG. 125. 500-μ scale applicable to figs. 105, 107-124.

PLATE 5

FIG. 126. Penis, basal plates, and paramera of *Hyperaspis undulata* (Say).
FIG. 127. Outline of the penis of *H. paludicola* Schwarz.
FIG. 128. Outline of the penis of *H. octavia* Casey.
FIG. 129. Outline of the penis of *H. punctata* Leconte.
FIG. 130. Outline of the penis of *H. quadrioculata quadrioculata* (Motschulsky).
FIG. 131. Outline of the penis of *H. disconotata disconotata* Mulsant.
FIG. 132. Outline of the penis of *H. trifurcata* Schaeffer.
FIG. 133. Outline of the penis of *H. spiculinota* Fall.
FIG. 134. Outline of the penis of *H. bolteri* Leconte.
FIG. 135. Outline of the penis of *H. simulatrix,* new species.
FIG. 136. Outline of the penis of *H. bensonica bensonica* Casey.
FIG. 137. Penis, basal plates, and paramera of *H. postica* Leconte.
FIG. 138. Outline of the penis of *H. dissoluta dissoluta* Crotch.
FIG. 139. Outline of the penis of *H. cincta* Leconte.
FIG. 140. Outline of the penis of *H. fimbriolata inflexa* Casey.
FIG. 141. Outline of the penis of *H. fimbriolata atlantica,* new subspecies.
FIG. 142. Outline of the penis of *H. sanctae-ritae,* new species.
FIG. 143. Outline of the penis of *H. psyche* Casey.
FIG. 144. Penis, basal plates, and paramera of *H. fimbriolata fimbriolata* Melsheimer.
FIG. 145. Penis, basal plates, and paramera of *H. proba proba* (Say).
FIG. 146. Penis, basal plates, and paramera of *H. biornata* Nunenmacher.
FIG. 147. Outline of the penis of *H. oregona,* new species.
FIG. 148. Outline of the penis of *H. annexa* Leconte.
FIG. 149. Outline of the penis of *H. quadrivittata quadrivittata* Leconte.
FIG. 150. Penis, basal plates, and paramera of *H. globula* Casey.
FIG. 151. 500-μ scale applicable to figs. 126-150.

PLATE 6

FIG. 152. Penis, basal plates, and paramera of *Hyperaspis lugubris* (Randall).
FIG. 153. Outline of the penis of *H. nunenmacheri* Casey.
FIG. 154. Outline of the penis of *H. taeniata cruenta* Leconte.
FIG. 155. Outline of the penis of *H. taeniata nevadica* Casey.
FIG. 156. Penis, basal plates, and paramera of *H. taeniata taeniata* Leconte.
FIG. 157. Spermatheca of *H. undulata* (Say).
FIG. 158. Spermatheca of *H. trifurcata* Schaeffer.
FIG. 159. Outline of the penis of *H. taeniata significans* Casey.
FIG. 160. Penis, basal plates, and paramera of *H. osculans* Leconte.
FIG. 161. Penis, basal plates, and paramera of *H. pleuralis* Casey.
FIG. 162. Spermatheca of *H. lateralis lateralis* Mulsant.
FIG. 163. Spermatheca of *H. proba proba* (Say).
FIG. 164. Spermatheca of *H. globula* Casey.
FIG. 165. Spermatheca of *H. binotata* (Say).
FIG. 166. Spermatheca of *H. rotunda* Casey.
FIG. 167. Antenna of *H. lateralis* Mulsant.
FIG. 168. Tarsal claws of *H. lateralis* Mulsant.
FIG. 169. Mandible of *H. lateralis* Mulsant.
FIG. 170. Maxillae and labium of *H. lateralis* Mulsant.
FIG. 171. 500-μ scale applicable to figs. 152-166.
FIG. 172. 500-μ scale applicable to figs. 167-170.

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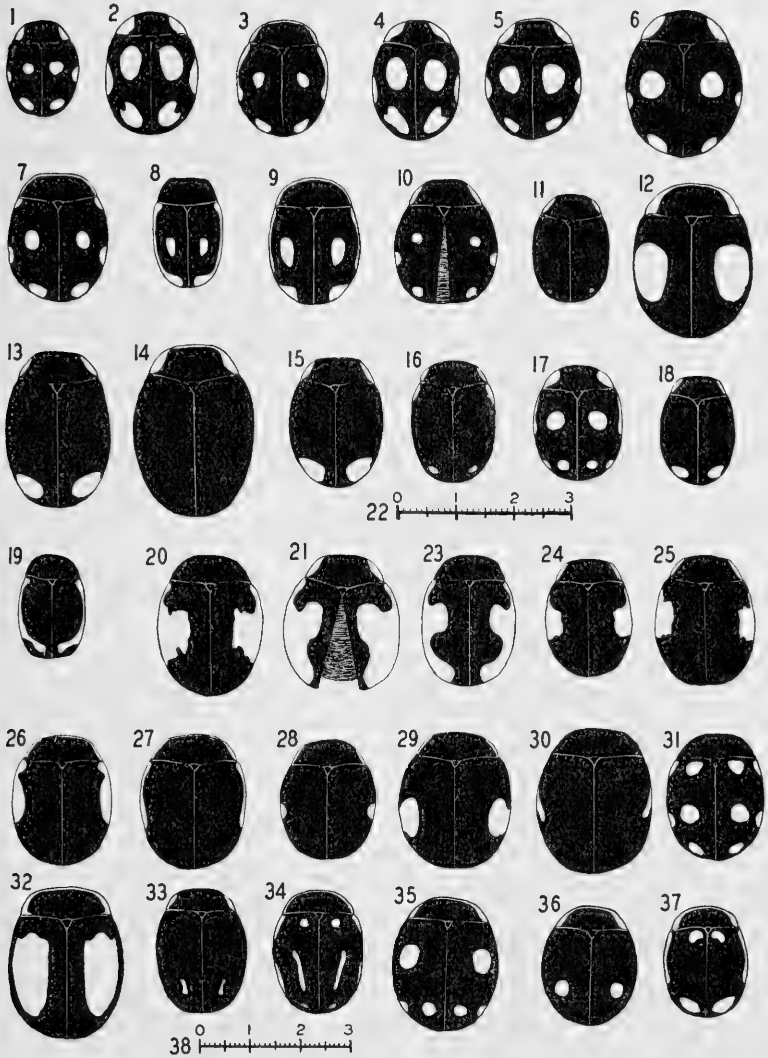
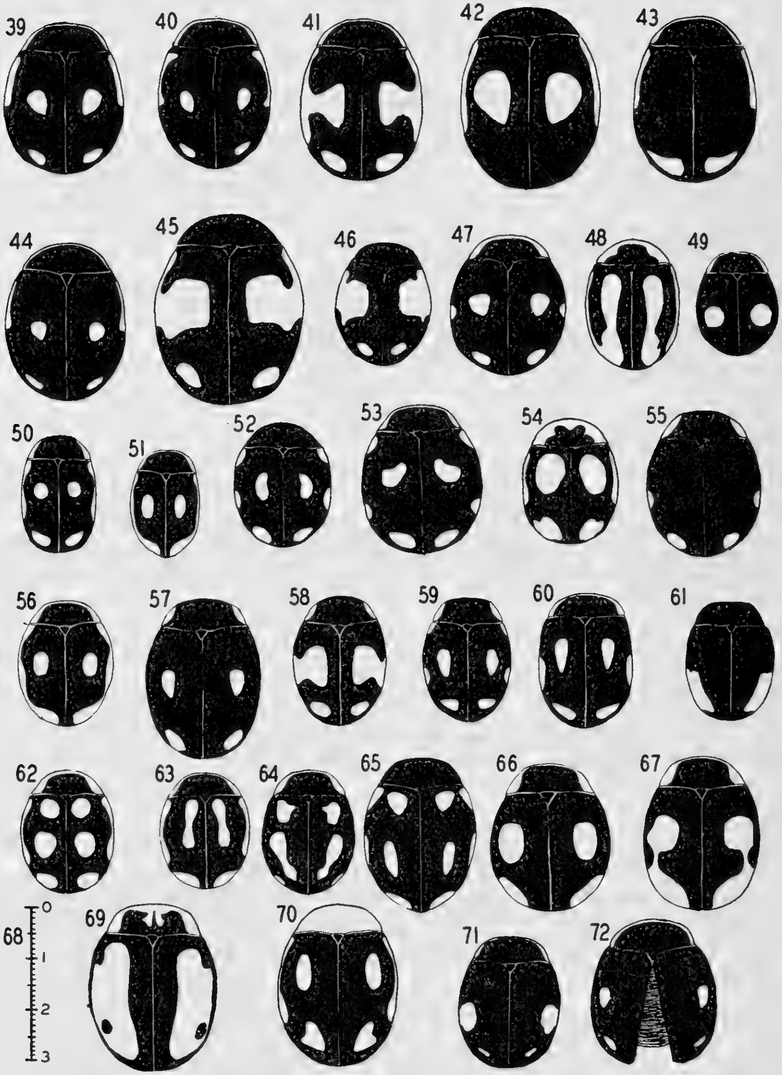


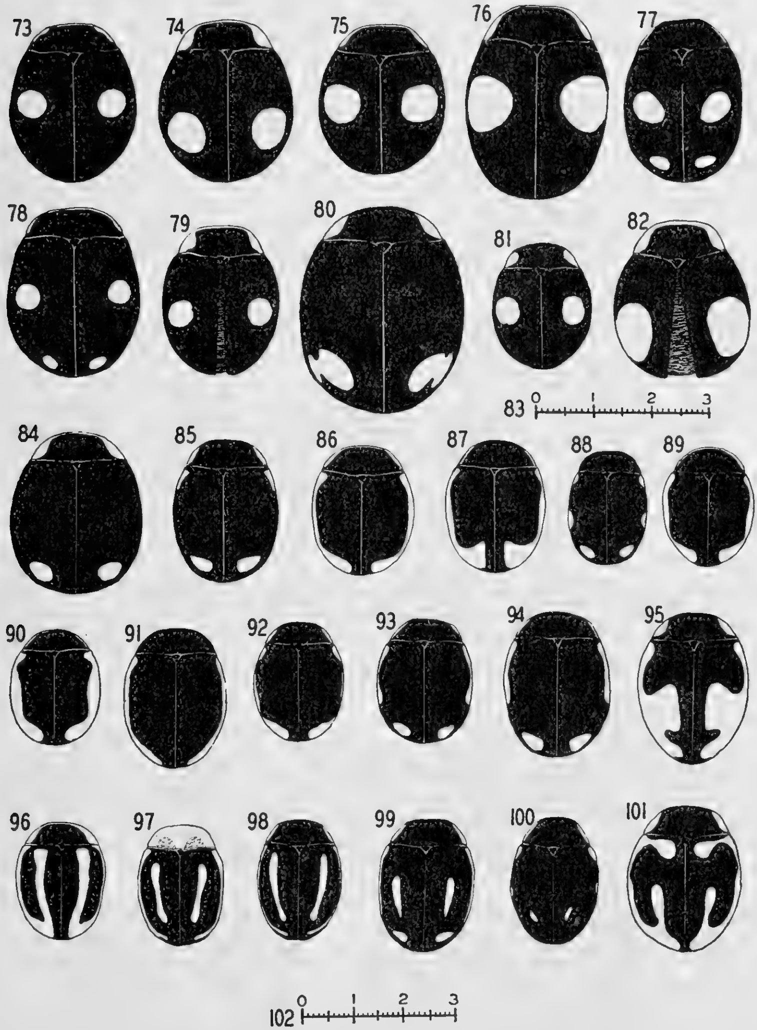
BEETLES OF THE GENUS HYPERASPIS INHABITING THE UNITED STATES

(For explanation of plate see pages 86-87.)



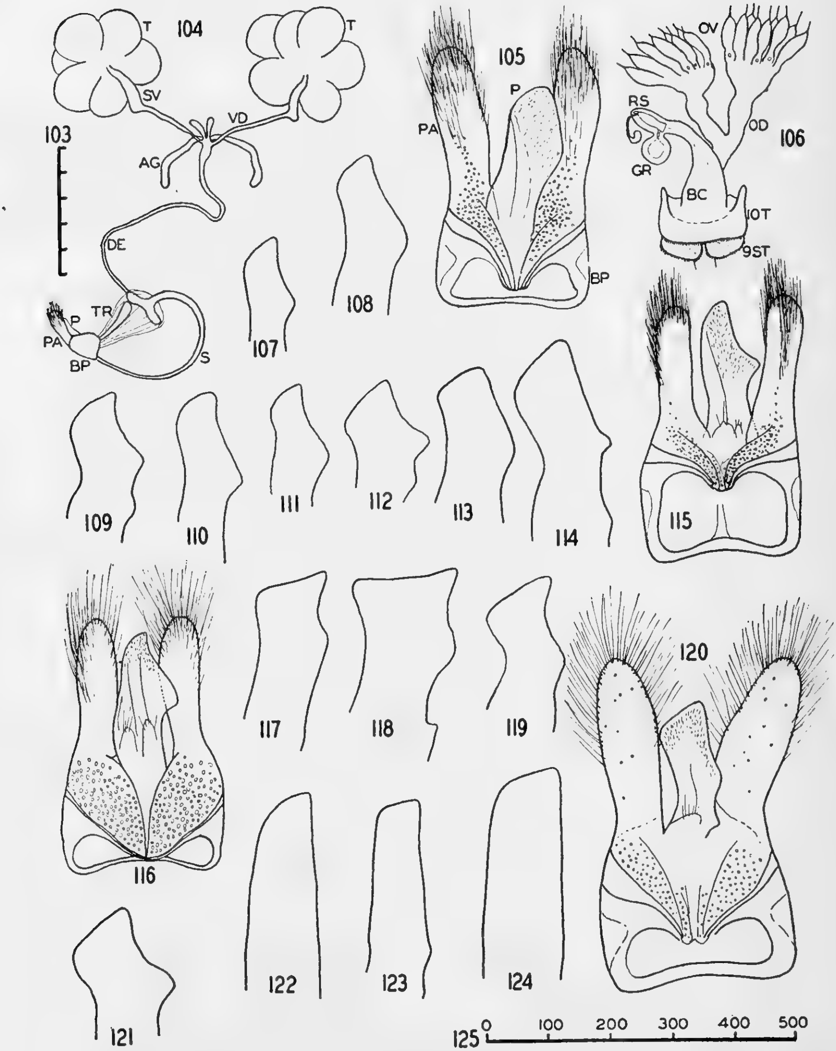
BEETLES OF THE GENUS HYPERASPIS INHABITING THE UNITED STATES

(For explanation of plate see pages 87-88.)



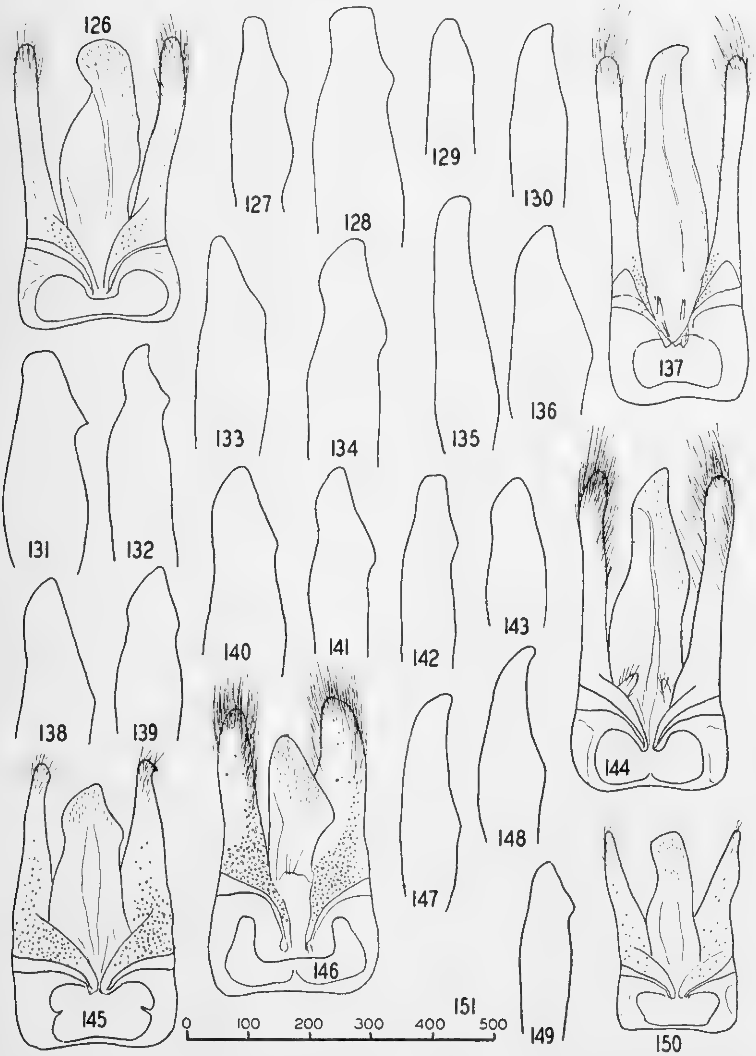
BEETLES OF THE GENUS HYPERASPIS INHABITING THE UNITED STATES

(For explanation of plate see page 88.)



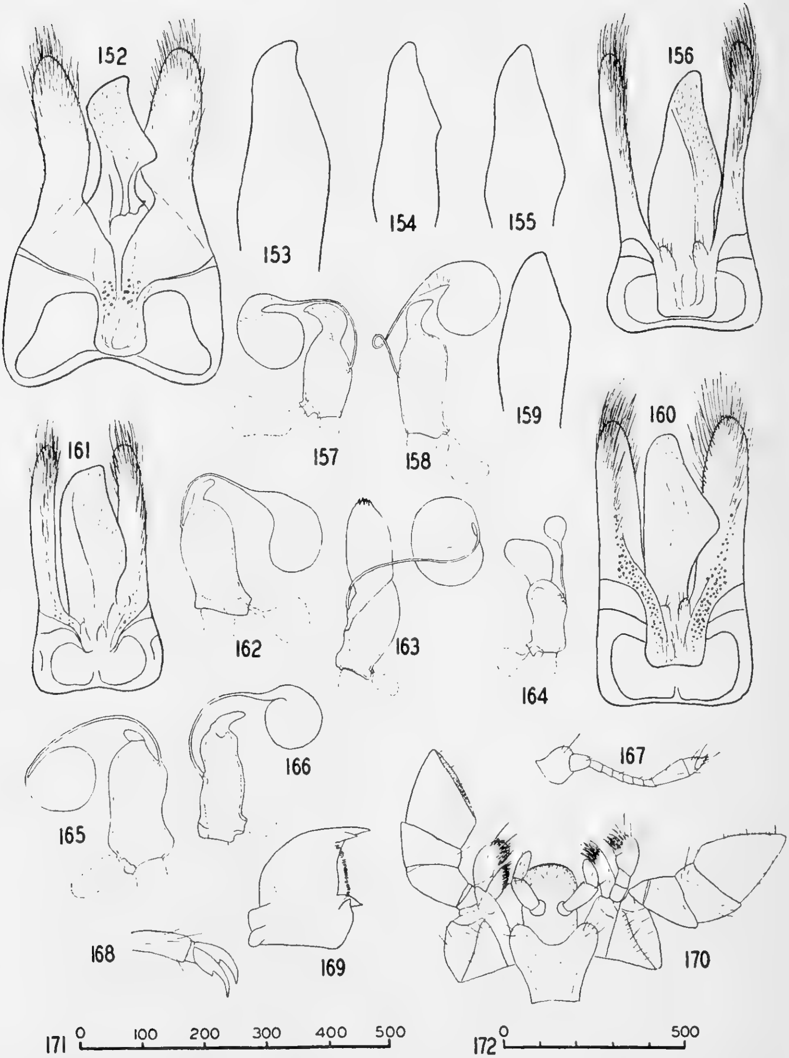
BEETLES OF THE GENUS HYPERASPIS INHABITING THE UNITED STATES

(For explanation of plate see pages 88-89.)



BEETLES OF THE GENUS HYPERASPIS INHABITING THE UNITED STATES

(For explanation of plate see page 89.)



BEETLES OF THE GENUS HYPERASPIS INHABITING THE UNITED STATES

(For explanation of plate see page 90.)

INDEX TO NAMES OF SPECIES AND SUBSPECIES OF HYPERASPIS AND OF THEIR SYNONYMS

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 101 NUMBER 7

ARCHEOLOGICAL REMAINS IN CENTRAL KANSAS AND THEIR POSSIBLE BEARING ON THE LOCATION OF QUIVIRA

(WITH 10 PLATES)

BY
WALDO R. WEDEL
Assistant Curator, Division of Archeology,
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CITY OF WASHINGTON
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(WITH 10 PLATES)

The archeological survey of Kansas begun by the United States National Museum in 1937, and continued each summer thereafter under the writer's direction, in 1940 was carried into the Arkansas River basin in the central and southern parts of the State. Archeological remains in this region had previously been accorded virtually no attention by trained investigators, though the presence of pottery-bearing sites was reported as long ago as 1873 (Mudge, 1896, p. 70). The Arkansas River is one of the largest streams of the central Great Plains, and its lower reaches in Oklahoma and Arkansas were formerly the seat of several highly advanced native civilizations. It was hoped that some of the village sites in its drainage basin in central Kansas might provide clues toward a cross dating of Plains cultures with lower Mississippi Valley archeological horizons. Added interest derived from the fact that certain large village sites in Rice and McPherson Counties have yielded Puebloan sherds and chain-mail fragments, and have been identified by local historians as the site of Coronado's province of Quivira.

Within the brief limits of this paper, I do not propose to detail either the archeological findings or the much-debated records of the various early Spanish exploring expeditions which may or may not have reached the area. With the topography of eastern New Mexico and western Texas I am not sufficiently familiar to be able to evaluate fully the Coronado and Oñate documents. Moreover, as regards the route of Coronado at least there is already a fairly extensive literature to which the interested reader is referred.[1] Indeed, this particular subject has been argued so often in the past that were it not for certain new considerations raised by recent field researches

[1] See especially Simpson, 1871; Winship, 1896; Hodge, *in* Brower, 1899; Baskett, 1912; Shine, 1916; Jones, 1929 and 1937.

there would be scant reason for reopening a problem toward whose ultimate solution I can contribute at present little else than archeological data.

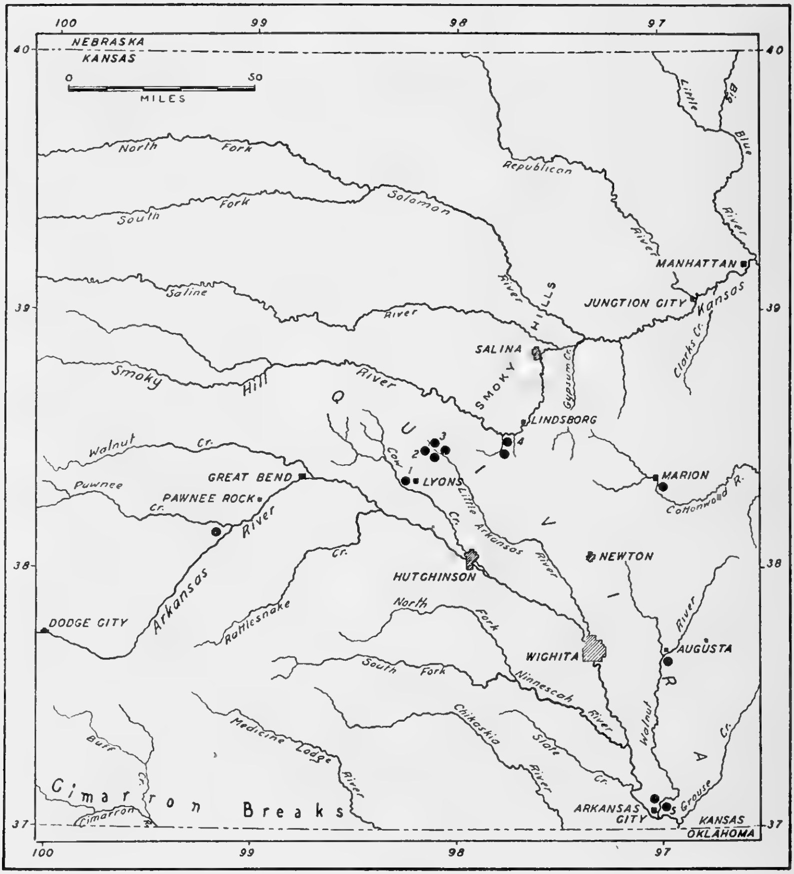

FIG. 1.—Map showing probable location of the province of Quivira during the sixteenth and seventeenth centuries. Solid circles indicate sites visited or partially excavated by the United States National Museum in 1940; not shown are numerous others reportedly of the same archeological horizon but as yet unchecked. Numbered sites include: 1, Malone site; 2, Tobias site; 3, Thompson site; 4, Udden site on Paint Creek; 5, Arkansas City Country Club site. All have yielded fragments of Rio Grande glaze-paint pottery; from 3 and 4 were taken chain-mail fragments.

The sites with which this paper primarily deals are situated (fig. 1) on Cow Creek and Little Arkansas River, in Rice County; on and between Sharps and Paint Creeks draining into Smoky Hill River in McPherson County; on Cottonwood River in Marion County; and on the Walnut River in Butler and Cowley Counties. I know of none on the immediate banks of the Arkansas itself, which are for the most part low and sandy and subject to devastating floods; or in the Neosho, Verdigris, and Fall River drainages of southeastern Kansas, which are still largely unexplored archeologically.

Only a few of these sites have been investigated as yet, and none exhaustively. Excavations were carried on by the National Museum at the Malone site on Cow Creek 4 miles west of Lyons, at the Tobias and Thompson sites about 5 miles southeast of Geneseo on the Little Arkansas, and on three sites lying northeast and east of Arkansas City on the lower Walnut. Short published reports are available on the Udden site on Paint Creek (Udden, 1900; Wedel, 1935), and I have seen a sample of the pottery and other materials from the nearby Swenson site on Sharps Creek. Surface collections only are available for other village sites southeast of Marion, south of Augusta, southwest of Larned, and in the valley of Grouse Creek east of Arkansas City. As far as my observations go, the materials from all these sites and localities are very similar, and there can be no reasonable doubt that all the communities indicated had essentially the same economic basis and material culture status.

These sites are, or prior to modern farming activities were, generally marked by low mounds on and between which are to be found an abundance and variety of artifacts. Contrary to local belief the mounds do not mark the former location of houses; there is no evidence in or under them of post molds, house floors, or fire pits. They consist of animal bones, ashes, broken pottery and other artifacts, and soil, and are in reality refuse dumps. Among them are to be found innumerable caches or storage pits, some of which attain a depth, and a diameter, of 8 or 9 feet. On the larger sites, as in Rice and McPherson Counties, these pits occur literally by the hundreds. From the ashy soil within them have been taken quantities of pottery fragments, chipped-flint artifacts, worked and unworked animal bones, charred maize, beans, wild-plum pits, and other village refuse. Persistent search has disclosed no evidence of house units, and it seems quite certain that the semisubterranean earth-covered lodge used by the Pawnee in northern Kansas and Nebraska was not characteristic of the peoples under consideration. At the same time, the numerous cache pits, refuse deposits, pottery remains, charred maize, and other materials argue for a fairly sedentary mode of life. For this, such easily transported skin structures as the tipi of the Plains hunting tribes would have been poorly adapted. I am of the opinion that an unexcavated semipermanent structure consisting of perishable materials is to be inferred. The familiar grass house of the Wichita (pl. 1) and their southern Caddoan kindred would probably fulfill these requirements; and, if erected on the ground surface rather than in a dug pit, such a dwelling would leave few or no surface traces a few years after abandonment.

On at least four village sites in Rice and McPherson Counties there are large ditched circles with mounded centers. The circles average about 90 to 120 feet in diameter, and are sometimes discontinuous. They have been locally termed "council-circles"; no village site has more than one. Excavations by the National Museum within such a circle at the Tobias site disclosed curving dug basins (Wedel, 1941, fig. 71) with post molds, hearths, successive floor levels, and quantities of burnt wattle-impressed clay. From one basin came disarticulated human bones. Some sort of specialized building, with a partially or wholly clay-daubed superstructure, is indicated. Dr. J. R. Swanton in conversation has suggested that these remains may mark the site of a temple or ritual center analogous to the community centers of the Caddo villages.

The items characteristic of the central Kansas sites may be briefly inventoried. Some are to be found among other established archeological horizons to the north and northeast; others are of more restricted distribution, and may prove diagnostic of the local complex. Since a detailed site-by-site analysis has not yet been made, I shall not attempt here to determine which elements are locally diagnostic.

The subsistence economy included horticulture, as well as hunting and gathering. Domestic plants included at least maize and beans. Hoes made from bison scapulae (pl. 6, *b*) were plentiful; the muller and mealing slab were extensively used. The principal game animal was undoubtedly the bison, but expert examination of the large quantities of bone refuse recovered will probably indicate the use of many other species. The bow and arrow may be inferred from the hundreds of small well-made triangular notched and unnotched stone points (pl. 5, *e, f*). Sturdy bone projectile points, usually with well-defined stems, are common (pl. 7, *d-f*); the socketed conical antler-tip point (pl. 7, *g*) was also known. All the sites yield grooved mauls (pl. 3 *c*) and great numbers of the familiar planoconvex end scrapers (pl. 5, *d*) as well as knives of various forms; the latter include the diamond-shaped and other beveled and unbeveled types (pl. 5, *a-c*). For use in skin working there are chipped drill points of straight and expanded-base types (pl. 5, *g-i*), many bone awls (pl. 7, *a-c*) and eyed needles (pl. 7, *h, i*), and wedge-shaped paint "brushes" made of cancellous bone (pl. 7, *k*). Pierced mussel shells (pl. 10, *d, e*) used as pendants, flat disk beads and perforated gorgets of shell (pl. 10, *b, c*), tubular bird-bone beads (pl. 7, *j, l, n*), hematite, and, very rarely, glass and turquoise beads (pl. 9, *a*) served for adorning the person or costume. Pipes are fairly common (pl. 8); they include typically an L-shaped form, and less commonly a projecting-stem variety, both made of fine-grained red sandstone often mistaken for catlinite. Tubular specimens, including one of soapstone (pl. 8, *f*) have been found at the Tobias site. Other items include mussel-shell spoons or scrapers (pl. 10, *f*), transversely scored ribs (pl. 6, *d*), large chipped stone blades (pl. 9, *b*), imperforate pottery disks (pl. 4, *f*), and spheroidal objects of cancellous bone. A coiled basket with single rod foundation (pl. 3, *b*) was uncovered during the work of the National Museum at the Tobias site.

Broken pottery is plentiful at most sites, and excavation has brought to light several restorable vessels. In Rice and McPherson Counties most of the ware is grit-tempered; on the Cowley County sites shell tempering is relatively more abundant and possibly predominant. With some exceptions the pottery is of mediocre quality, and looks like the result of a decadent industry. The usual form is a jar from 8 to 12 inches tall with vertical rim, rounding shoulder, subconical underbody, and flat or round-pointed base (pls. 2; 3, *a*) Commonly, two handles (pls. 2, *a*; 4 *a, b, g-i*) connect the neck and upperbody, these usually being attached by riveting. The lip, if not plain, bears small incised or stroked units. Vessel surfaces, usually brown to gray in color, are either smoothed, or else have low subparallel ridges which give a corrugated or stamped effect. This surface finish may have been achieved by paddling with a scored rib of the type mentioned above (Wedel and Hill, no date). Incised neck or body decoration is virtually nonexistent; fillets applied below the rim are about equally rare. A small proportion of the sherds have cord-roughened exteriors strikingly reminiscent of the prehistoric Upper Republican wares, from which they may have been derived. There are a few red "slipped" fragments that may have been traded in from peoples to the south or southeast, and at the Udden site on Paint Creek has been found part of an incised pot with "cloistered" rim (Udden, 1900, fig. 10) which unquestionably shows protohistoric Pawnee influences (cf. Dunlevy, 1936, pls. 2, 3, 6, 7; and Wedel, 1938, pls. 4 and 5). On the whole, however, the pottery is readily distinguishable from all known Pawnee wares, as well as from the Oneota and other pottery types so far reported to the north, northeast, and east. To a considerable degree, this statement holds for the local archeological complex as a whole.[2]

In addition to the artifacts of local Indian manufacture just described, there are other specimens that afford important clues to the time of occupation and to the relationships of the natives with other peoples and localities. A very characteristic banded chert containing fusulinid fossils (pl. 9, *b*) and said to come from aboriginal quarries near Maple City, Kans., and Hardy, Okla., was traded in some quantities as far northwest as Rice County. A foreign provenience must also be accepted for turquoise beads, obsidian, glaze-paint potsherds, and for the very limited European articles of glass and metal.

Potsherds with glaze-paint decoration have been picked up from time to time on the surface of several sites on Cow Creek and Little Arkansas River. A number of these surface finds, together with other similar fragments unearthed by the National Museum party in cache pits and mounds on the Tobias site in northeastern Rice County, were submitted to Dr. H. P. Mera, of the Laboratory of Anthropology at Santa Fe. Mera states (letter of August 13, 1940) that they represent "without question, late Rio Grande forms which began to appear as early as the first quarter of the sixteenth century and continued with few changes until about the middle of the seventeenth century. After this latter date the quality of glaze generally became so poor that I feel sure that your examples can safely be assigned to the period mentioned. All of these would come within my Group E." The glaze-paint sherds from the Tobias site have also been examined by Dr. A. V. Kidder, who reports (letter of May 6, 1941) that they are "certainly Rio Grande glazes, most of which would be grouped as Glaze IV if they came from Pecos, although they might be somewhat later if from farther west. As there are no bowl rims one cannot be absolutely certain but I agree with Mera that 1525 to 1650 would certainly cover them. In fact, I would prefer to place them prior to 1550. . . . ." Other glaze-paint sherds from surface collections in Rice County fall in Mera's "Group C and were in style for a short time during the last half of 15th century." It is noteworthy that none of the Puebloan sherds reported on by Drs. Mera and Kidder are of types made after ca. 1650.

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[2] Contrary to some local views, I see no evidence whatever for regarding the Whiteford burial pit east of Salina as belonging to the manifestation under discussion. The associated pottery types and earth-lodge dwellings pretty definitely align these burials with a different and earlier people probably more closely related to the prehistoric Upper Republican horizon.

That definite trade relations existed with the Rio Grande pueblos is further demonstrated by the finding of turquoise in and on Rice County sites. It is possible that the obsidian not infrequently used for arrowpoints in the locality also came from New Mexico, although Yellowstone offers an alternative but more distant source. We know further that this trade was going on at a time when white men were in contact with the Indians, for the same sites which yield glaze-paint sherds, turquoise, and obsidian also contain rare glass beads and objects of iron. These last items can probably be regarded as of Spanish origin, obtained directly or indirectly through contacts with white men in, or operating from, the Rio Grande Valley.

Among the objects of European provenience, probably the most interesting yet found are several fragments of chain mail. The first of these was unearthed prior to 1890 by Udden (1900) in a refuse mound on Paint Creek about 4 miles southwest of Lindsborg. Additional pieces were recovered in 1940 by the National Museum in a cache pit and nearby refuse heap at the Tobias site, about 25 miles west of Paint Creek. Udden's specimen has since been lost but from the description and surviving illustration it appears to have been essentially like the recent Rice County finds. The rings in each case average circa $\frac{3}{8}$ inch in diameter.

Just what significance is to be attached to these chain-mail fragments is not clear. One is tempted to think of them as possible relics from some early Spanish exploring expedition out of the present New Mexico region. The heyday of chain mail in Europe, according to Dean (1930, p. 50), was the tenth through the twelfth centuries, and its use had been largely discontinued by military forces long before the time of Coronado and his contemporaries. The same authority, observing that ". . . . European chain mail was rarely made after 1600 . . . . ," figures suits of plate armor from the Maximilian period (1500-1540) in which mail was used for brayettes or groin defenses (op. cit., figs. 65, 67, 72, 75, 91). In Coronado's muster roll (Aiton, 1939) and also in the list of equipment requisitioned by Oñate (Hackett, 1923, p. 229) there are references to "cueras de malla" or "cotas de malla," which has been translated as coats of mail. It appears, however, that when chain mail was superseded by plate armor, the latter was frequently though inaccurately designated by the same term as its predecessor. For this reason it is exceedingly difficult, if not impossible, to determine from the surviving documents whether the coats of mail carried by these and other sixteenth- and early seventeenth-century explorers consisted of true chain fabric or, alternatively, of overlapping plates or scales.[3]

In this connection we may note a possibly significant clue in the narratives of the De Soto expedition. Describing the weapons used by the natives of Florida, the gentleman of Elvas says of certain of the arrows (Robertson, 1933, p. 37): "Those of cane split and enter through the links of mail [malhas] and are more hurtful. . . . ."

Apparently not all of the extant translations agree on this rendering of the term "malhas." It is difficult to see, however, how the splitting of a cane arrow would be "more hurtful" on another type of armor, as for example on a cuirass of plate, than would one of the other arrow types previously listed by Elvas as having unusual penetrating power. There is at least an implication in this passage that chain mail was worn by members of De Soto's party; and since this expedition was to all practical intent contemporaneous with that of Coronado it is entirely within reason to believe that similar equipment was used by Coronado's men. Whether subsequent exploring or punitive expeditions into the Great Plains were similarly armored I am unable to say.

In answer to my query, Mr. Thomas T. Hooper, City Art Museum of St. Louis, has commented as follows (letter of June 10, 1941) on the use of chain mail in the American Southwest:

> In discussing archeological finds there is too often, I think, the tendency to assume that certain types of objects were specifically in use during certain limited periods and never thereafter. In the case of European expeditions to this country it seems to me entirely possible that many items of equipment might have been taken along which would have been "out of fashion" in the courts of Europe. It is true that chain mail ceased to be worn in Europe extensively after the 16th century but during practically all of that century it was used as supplementary protection for the joints which could less easily be guarded by plate: the elbows, armpits, and groin. It seems to me entirely possible that mercenary soldiers or adventurers might, especially in a land where their possible opponents were known to be fond of the bow and arrow, continue to wear such reinforcing patches of mail until a very late period.

From this it would appear that the chain-mail specimens in themselves are not likely to throw much light on the period of occupancy represented by the sites under consideration.

Despite the fact that some of these sites were obviously inhabited since the beginning of contact with white men, and that they indi-

[3] Cf. Curtis, 1927, p. 109. In response to a direct inquiry Aiton (letter of January 4, 1941) says "I am certain that the *cueras* and *cotas de malla* in the Coronado accounts refer to link or chain mail and not to overlapping plates or scales. . . . ."

cate the former presence of a comparatively widespread and numerous people, their identification in terms of historic tribal groups is not easy. As already noted, the remains as a whole are quite distinct from those found on Pawnee sites in northern Kansas and Nebraska (Strong, 1935, p. 57; Wedel, 1936) though there are a number of resemblances. Unlike the Pawnee, who clung to their territory in central Nebraska from pre-Spanish days until 1875, and whose remains consequently have been identified through exploration at documented village sites, the erstwhile inhabitants of the protohistoric sites in central Kansas were gone by the time American explorations west of the Missouri set in. Pike traversed a part of the region between the Smoky Hill and Arkansas in 1804, but neither he nor his successors made any mention of villages of sedentary farming Indians. What is evidently Cow Creek is shown on Pike's map (reproduced in part in Wedel, op. cit., map 9) as buffalo range; to the south, across the Arkansas, were the hunting grounds of the Pawnee and Kansa. Without exception the maps purporting to show this territory prior to 1800 are so sketchy or inaccurate that they have decidedly secondary value in tracing the early native occupancy.

The recurrence at several widely separated sites of Puebloan sherds attributed to the period 1525-1650 is strong evidence that these villages were flourishing during the sixteenth and seventeenth centuries—that is, at about the time the Spaniards were exploring and beginning to develop the country along the upper Rio Grande. It may be significant therefore that from the time of Coronado (1541) until at least the latter part of the seventeenth century, Spanish exploring parties repeatedly visited, or heard reports concerning, farming Indians who dwelt in grass-house villages in the province of Quivira northeast of the Rio Grande pueblos. Coronado, of whom we shall have more to say presently, was followed about 1594 by Bonilla and Humaña, and in 1601 by Oñate. Both of these later expeditions saw large rancherias of grass lodges on a stream identified as the Arkansas (Bolton, 1916, pp. 200, 250-267). Sometime later, apparently between 1664 and 1680, while in pursuit of Puebloan fugitives at El Cuartelejo in the western plains north of the Arkansas, Archuleta found them in possession of kettles, copper, and tin acquired by journeys eastward to the Quiviran settlements. From this circumstance, the Spaniards "inferred it to be a kingdom very civilized and wealthy" (Thomas, 1935, pp. 53, 261). The ill-fated Villazur expedition, headed for the Platte and a crushing defeat, passed through El Cuartelejo in 1720, but there is no way of determining from the published record whether Quiviran towns still stood to the east. The Du Pratz map of 1757 (partly reproduced in Wedel, op. cit., map 5) shows only the *Panis blancs* (Pawnee) at head of the R. Blanche between the Smoky Hill and Arkansas Rivers, and our sites are not Pawnee. In short, it appears that the grass-house communities of Quivira in the plains northeast of Santa Fe were abandoned some time between 1664 and 1757.

The repeated references by the Spaniards to grass houses and a sedentary horticultural mode of life in Quivira have been commonly interpreted as a description of the Wichita (Hodge *in* Brower, 1899, pp. 69-72; see also Handbook of American Indians, Bur. Amer. Ethnol. Bull. 30, pt. 2, pp. 346, 947). Judging from traditions and other evidence which we shall not detail tribes or bands belonging to this confederacy were at one time on intimate terms with the Pawnee of Nebraska.[4] They were apparently the northernmost group of grass-house Caddoans as contrasted to the earth-lodge-using Pawnee and Arikara. Their history and movements previous to circa 1700 are still veiled in uncertainty; since that date they seem to have resided with related tribes at various localities on the lower Arkansas, Red, Brazos, and Trinity Rivers in present Oklahoma and Texas (Bolton, 1914, pp. 23, 43). On present evidence it seems to me that the archeological findings in central Kansas, insofar as direct comparisons are feasible, are in accord both with what is said by the Spaniards concerning Quivira and also with what we know concerning historic Wichita material culture (Dorsey, 1904, pp. 4-6).

CORONADO AND QUIVIRA

On present information the archeological remains inventoried in the foregoing pages constitute one of the most characteristic and noteworthy manifestations of aboriginal culture in Kansas. If correctly assigned to the late sixteenth and early seventeenth centuries, they offer a chronological point of reference tied in with the first European contacts in the central Great Plains. They assume additional interest because Bandelier, Winship, Hodge, and others have suggested that the Quiviran settlements visited by Coronado lay somewhere in central or east-central Kansas on or near the Smoky

[4] Sarfert (1908, p. 148) has suggested that the natives of Quivira may have been the Pawnee who still retained the southern Caddoan grass dwelling and only later developed or took over the earth lodge. Recent archeological researches have shown, however, that the earth-covered pit house was widely used throughout the central plains in prehistoric times (Strong, 1935, p. 276; Wedel, 1940, p. 320), and that the Pawnee since at least their first trade contacts with white men were already using the earth lodge and not the grass house.

Hill-Kansas Rivers. Since discovery of the large protohistoric sites in Rice and McPherson Counties, Jones (1929, 1937) has stoutly maintained that the earlier students of Coronado's route went too far east or northeast and that the villages seen by this expedition were on Cow Creek and Little Arkansas River not far from the present town of Lyons. Let us see in how far the extant narratives of the Coronado adventure support this latter view.

Jaramillo's brief eye-witness account of Quivira and its environs, including the approach from the southwest, seems to me to be a strikingly faithful description of the central Kansas region. Thus, he observes (Hammond and Rey, 1940, p. 303) that on the feast day of Saints Peter and Paul (Wednesday, June 29), after approximately 30 days march north from the point where the army was left,

> We came to a river that we found there below Quivira. Upon reaching this river the Indian [Isopete] recognized it and said that it was the one and that the settlements were down the stream. We crossed it at that place and followed it downstream along the opposite north bank, turning our route to the northeast. After traveling for three days we met some Indians who were out hunting, killing cattle to take meat to their pueblo which was about 3 or 4 days from us, farther down. . . . . Once the Indians left for their homes, which were at the distance mentioned we too proceeded by our regular journeys until we reached the settlements. We found them[5] on arroyos [which] though not of much water [were] good and had good banks, which enter the other larger one mentioned; there were, if I remember right, six or seven villages one apart from the other; passing through which we traveled 4 or 5 days, it being understood that the country is uninhabited between one of these arroyos and the other. We reached the back country of Quivira, according to what they said, which they told us there was much of, which they designated to us as teucarea. This was a river of more water and settlements than the others. . . . .

The Arkansas River in west-central Kansas turns toward the northeast about 20 miles below Dodge City, which direction it pursues for some 70 miles to the town of Great Bend. Here it flows east for about 10 miles, thence turning southeastward to the Oklahoma line. If Coronado crossed the stream a few miles below Dodge City, perhaps near the present Ford, and then followed its "opposite north bank" his route would very soon have turned to the northeast, as Jaramillo says it did. The Quiviran hunting party would have been encountered about halfway down this bend, between the present towns of Kinsley and Larned. Another 3 or 4 days to the main settle-

[5] Throughout the remainder of this passage I am following a translation made from the Spanish of Buckingham Smith (1857) by Drs. J. P. Harrington and J. R. Swanton, of the Bureau of American Ethnology. This differs in certain possibly significant details from the published translations of Winship and of Hammond and Rey.

ments—a total of 30 leagues, or about 80 miles, below the crossing, according to the Relacion del Suceso, would have taken the expedition around the northernmost point of the great bend.

It is possible that the first settlement, after the hunting camp, was seen in the vicinity of the present town of Great Bend. So far as I am aware, archeological sites assignable to the Coronado period have not been reported from this locality. Jaramillo's account suggests, in fact, that the party left the main river valley, probably marching overland in an easterly or northeasterly direction where the river again swings to the south. Such a course would have taken the explorers directly to the village sites on Cow Creek in western Rice County. One of the largest of these—the Malone site 4 miles west of Lyons—is about 100 miles from Ford, which is not greatly in excess of the 30 leagues given by the Relacion del Suceso. This site, together with others nearby and those on Little Arkansas River northeast of Lyons, are on streams which, to paraphrase Jaramillo, although not having much water are good and have fine banks and flow into the larger one mentioned, i. e., into the Arkansas. Between these populated lesser streams the upland prairies were uninhabited, says Jaramillo, and precisely the same situation is shown by the archeology of the Rice-McPherson County locale.

The various documents leave us in some doubt as to the length of time spent in Quivira, the distance and direction traveled to reach its limits, and the number and size of the settlements seen. Coronado, in his report to the king, states that there were not more than 25 villages, and that he spent 25 days examining the province. The Relacion del Suceso says he marched 25 leagues through the settlements. Jaramillo's account is not very explicit, but he indicates that if his memory was trustworthy it was "past the middle of August" when the return trip was begun. This is probably an error. In any event, there is no proof that the party traveled any great distance in Quivira. Many days were doubtless spent in resting and refreshing men and horses preparatory to the return journey, in summoning and waiting for the chief of Arahe, in councils with the natives, and in similar activities. From the standpoint of archeology, it should be noted that among the known sites on Cow Creek, on Little Arkansas River, and farther east on the tributaries of Smoky Hill River in McPherson County there are easily six or seven large villages sufficiently removed from one another to have required 4 or 5 days' marching, as Jaramillo reports. Since closely related sites occur as far east as Marion on the upper Cottonwood, and also southeastward down the Arkansas drainage, I believe Coronado could easily have spent 25 days and counted up to 25 villages south of Smoky Hill River within 100 miles of the present town of Great Bend. I see no reason whatever to assume that Coronado crossed the Smoky Hill-Kansas Rivers, and am inclined to believe that this was the stream at the end of Quivira—with more water and more inhabitants than the others—as it also appears to be the northern limit of archeological sites of the type discussed earlier in this paper. There is no evidence that the expedition crossed the Smoky Hill, Saline, Solomon, and Republican, as Hodge suggested, nor have any traces of protohistoric sites of the Coronado period come to light in that area.

For Quivira as a land Coronado had only words of praise. The soil was rich and black, well watered with arroyos, springs, and rivers, and abounding with plums, grapes, and mulberries. It was, he said, the best country he had seen in his long trek. All of these observations fit the Rice-McPherson County locality, which differs sharply from the terrain to the southwest and from the plains south of the Arkansas River. As for the natives, whose fabled riches had lured him thence, they were savage and bestial though they received him peaceably enough. Their houses, round in form, were of straw; according to the Relacion del Suceso some of the villages had as many as 200 lodges. The people grew maize, beans, and calabashes, in addition to which they hunted the bison. They had no cotton or domestic fowls, and clothed themselves in animal hides. One Indian wore a copper breast piece or pendant, but otherwise no native metal was found.

There is little in the above characterization which would enable the present-day student to distinguish the Quivirans from the inhabitants of other nearby horticultural communities, such as the Pawnee or their supposed Siouan contemporaries to the east. The persistent references to straw houses, however, rules out the Pawnees with their earth lodges. It also eliminates from serious consideration most of the village sites in the Kansas drainage east of the 97th meridian, *i. e.*, below Junction City, where Brower and apparently Hodge were inclined to look for Quivira. My own survey of that region shows that these sites are generally littered with cord-impressed pottery such as is associated in northern Kansas and Nebraska with the prehistoric rectangular semisubterranean earth lodge. Furthermore, there is as yet no shred of evidence that any of the known archeological sites east of Salina date from the early white contact period as do the sites mentioned in Rice and McPherson Counties.

As one may readily judge from the widely divergent conclusions reached by various students from time to time, identification of the route taken by Coronado from Pecos to Quivira is not a simple matter. The extant narratives are essentially summaries written months or years after the events recorded had transpired. The exact distance and direction of travel each day is nowhere stated, and apparently neither map nor journal was kept. On a number of points there are discrepancies between one account and another. Some of these can be reconciled; others are extremely difficult to dispose of satisfactorily. We are dealing, in short, with probabilities; hence it is not to be expected that the exact line of march from beginning to end will ever be conclusively established.

All attempts to reconstruct Coronado's route during the summer of 1541 are based on the identification of two pueblos in the Rio Grande area. Tiguex, where the army was quartered while awaiting Coronado's return from Quivira, was located where the present town of Bernalillo, N. Mex., stands. Cicuye, last pueblo seen by the army before it entered the buffalo plains, is identified with the ruins of Pecos.

In the matter of chronology there are apparently two established points. Coronado, in his letter of October 20, 1541, to the king, says he left Tiguex on April 23. Castañeda, presumably from memory, gives May 5 as the day of departure. Coronado's date fits the subsequent narratives rather better, and since he was writing within a month or two of his return from Quivira, his statement probably merits greater weight. The second fixed date is Wednesday, June 29, "the feast day of Saints Peter and Paul," on which Coronado's picked band crossed a river below Quivira. As far as I am aware, the date on which this detachment returned to Tiguex is nowhere stated.

Leaving Tiguex on April 23, then, Coronado and his army marched southeast (see Hodge *in* Brower, 1899, p. 60) to cross the Pecos River after 4 days, whence they proceeded in a more easterly direction. According to Coronado (Hammond and Rey, 1940, p. 186), they traveled for 17 days to reach a Querecho rancheria; after another 5 days, they "reached some plains as bare of landmarks as if we were surrounded by the sea." Here the native guides lost their bearings "because there is nowhere a stone, hill, tree, bush, or anything of the sort . . . . we wandered aimlessly over these plains. . . . ." Finally, their food supplies exhausted, the Spanish held a council and Coronado with 30 picked horsemen (and 6 foot soldiers ?) rode northward in search of Quivira. Coronado does not state how long the army "wandered aimlessly" or how many days they had traveled when he turned north (see footnote 6, p. 16). Castañeda (Hammond and Rey, 1940, p. 239) says they had traveled 37 days of from 6 to 7 leagues each, and that they were then 250 leagues from the settlements, *i. e.,* Tiguex. They were also among some arroyos and barrancas. At the last barranca, "which extended a league from bank to bank" and had a small stream at the bottom, the council was held and the army remained to rest many days before returning to Tiguex while Coronado headed north. The Relacion del Suceso (Hammond and Rey, 1940, p. 291) says they had marched 150 leagues, 100 to the east and 50 to the south.

It is not easy to harmonize all these varying statements of distance, particularly since the army seems to have spent nearly or quite 2 weeks in purposeless wandering. There can be no doubt, I think, that the plains without landmarks were the Staked Plains of Texas. Hodge (Brower, 1899, p. 64), accepting Castañeda's figure of 250 leagues, was of the opinion that the Staked Plains had been crossed and that the expedition divided on the Colorado River in central Texas—probably "well along the stream, say between longitude 99° and 100°." Relacion del Suceso would put the point of separation somewhat farther north.

Both Jaramillo and Castañeda say that the expedition divided in or near a large ravine—"una barranca grande como las de colima," as Castañeda has it. Whether the valley of the Colorado at the location given by Hodge, or the North Fork of the Canadian as Winship suggests (Winship, 1896, p. 399), would fit this description, I leave to students familiar with local topographic conditions. Considering the aimless wandering mentioned by Coronado, I am of the opinion, however, that Hodge took the expedition much too far to the southeast, and that Winship erred equally in taking it into central or eastern Oklahoma. From either of these points north the expedition would have crossed numerous streams and rivers, which is at variance with Coronado's later words.

Castañeda's comparison of the last barranca with those of Colima on the west coast of Mexico raises an interesting point. It suggests that he was describing no ordinary gully or arroyo such as one might see anywhere along the edge of the High Plains, but rather a considerable canyon or gorge. It is possible that Castañeda's memory was playing tricks on him, and that his recollection of the barranca was altogether out of line with reality. On the other hand, Donoghue (1929, p. 189) may be right in his contention that the wanderings of the army had taken it more or less in circles and that this last barranca was none other than Palo Duro Canyon and its branches in Randall and Armstrong Counties, Tex. This remarkable canyon, with its precipitous walls, its depth of 700 to 900 feet and a width of $1\frac{1}{2}$ to 5 miles (Gould, 1906, p. 12; 1907, p. 10) would certainly have profoundly impressed the Spaniards after the weeks spent on the monotonous plains. One objection to this identification is that Palo Duro Canyon is under 300 miles, or a little over 100 leagues, east by slightly south of Pecos. This is not so far from the Relacion del Suceso's 150 leagues if we assume that one-third of the distance was given over to the aimless wandering mentioned by Coronado. It does not square with Castañeda's estimate of 250 leagues.

From the point where he left the army, possibly at Palo Duro Canyon or somewhere not far away to the south or southeast, Coronado says (Hammond and Rey, 1940, p. 187) he traveled 42 days and that "after traveling 77 days [from Tiguex] over these barren lands" he reached the province of Quivira. Castañeda (ibid., p. 241), who was not among those selected to accompany his commander north, states that the journey to Quivira required 48 days. According to the Relacion del Suceso (ibid., p. 291), "after traveling many days by the needle God was pleased that in 30 days we should come to the Quivira River. It is reached 30 leagues before coming to the settlement of the same name." Jaramillo (ibid., p. 302) observes that "Turning always to the north from here, we continued on our way for more than 30 days, or close to 30 days of travel, although the marches were not long, without ever lacking water in all these days . . . . So on the feast day of Saints Peter and Paul [June 29] we came to a river that we found there below Quivira." The settlements of Quivira, he says further, were another 6 or 7 days' journey down this stream.[6]

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[6] Excepting Castañeda's statement that 48 days were required for Coronado's trip to Quivira, the varying figures just given from the several accounts for the number of days traveled are not so disparate as they seem at first glance. Jaramillo and the Relacion del Suceso both say that the river below Quivira was reached in 30 days, and that it was another 30 leagues (Relacion del Suceso) or 6 or 7 days (Jaramillo) to the Quiviran towns. This gives a total of about 36 or 37 days to Quivira, as against Coronado's 42 days. Figuring back 30 days from the crossing of the "Quivira River" on June 29, the northward dash would have begun on or about May 31. This can be checked against Castañeda's assertion that the expedition had traveled 37 days to reach the barranca where the separation occurred. Thirty-seven days after April 23 would be May 30.

It will be recalled that Coronado says the plains without landmarks were reached after 22 days' travel, i.e., about May 15. If the dates given above are substantially correct, and the expedition was not divided until May 30 or 31, about 2 weeks were given over to aimless wandering through the Staked Plains.

The chroniclers of the expedition have vouchsafed almost no details concerning the nature of the terrain traversed during this march to the north. Coronado remarks on the great numbers of bison seen, on which the party mainly subsisted. Also he observes (Hammond and Rey, 1940, p. 187) that "we went without water for many days and had to cook our food on cow dung, because there is no other fuel in all these plains, except along the arroyos and rivers of which there are very few." Jaramillo, it will be remembered, says the party did not lack water at any time and that the march was by easy stages. If this leg of the journey began in the general vicinity of Palo Duro Canyon, or to the south, a northerly route to the Arkansas would have led across few rivers indeed—the Canadian, the North Canadian, the Cimarron, and a few secondary streams. Each of these major streams flows in a deep but relatively broad valley, and between watercourses the flat High Plains topography continues northward from the Texas Panhandle for hundreds of miles.

We can only guess at Jaramillo's meaning when he says the day-by-day marches were not long ones. Previously, according to Castañeda, the army had marched 6 or 7 leagues, about 15 to 18 miles, daily. Hodge, noting that the airline distance from the Rio Colorado of Texas to the Arkansas River near Dodge City is about 440 miles, points out that this could have been traversed in 35 days at 12½ miles per day. From Palo Duro Canyon, on the other hand, the Arkansas is distant only about 250 miles, or less than 8 miles per day of continuous marching. This figure seems very low for a small party consisting largely or entirely of picked horsemen. Still, we have Jaramillo's statement that it was 6 or 7 days' travel from the crossing of the river on Saints Peter and Paul's day to the settlements of Quivira, and the Relacion del Suceso gives this distance as 30 leagues. Here the daily mileage would have been 10 or 12. It is possible that the party rested frequently or for some other reason loitered along the road so that the average distance covered during this march did not much exceed 8 miles a day. On the other hand, they may have started farther south than Palo Duro Canyon. In any event, in the light of what follows in the narratives concerning the river and province of Quivira, I agree entirely with Hodge and others who point out that the Arkansas is the only river within 30 days' easy march north of central or panhandle Texas which can reasonably be considered as the one crossed by the Spaniards on June 29, 1541.

One further point should be noted here. After leaving the army, according to Jaramillo and the Relacion del Suceso, Coronado traveled to the north. A due northward course from Palo Duro Canyon or from any other point along the east front of the Staked Plains would have brought the party to the Arkansas near Garden City, about 75 miles above the place where the river turns to the northeast. Jaramillo's statement suggests that the crossing took place much lower down and nearer the bend. An approach from due south to the Arkansas below Dodge City would have taken the party across the western part of the Cimarron Breaks in southern Meade and Clark Counties, Kans. Here the terrain is rugged and broken, in striking contrast to the flat plains to the west and north. One wonders whether such an area, if crossed by Coronado, would have escaped some notice in at least one of the narratives. Had the party marched northward from Texas to the vicinity of Meade, or a little farther west, thence northeast for a day or two, and then north again, it would have traveled almost altogether through a High Plains terrain and would have reached the Arkansas near the present town of Ford.

OÑATE AND QUIVIRA

In the half century following their discovery by Coronado, the settlements of Quivira were visited by Spanish expeditions on at least two other occasions. The first of these was under Bonilla and Humaña who, in 1593 or 1594, led a party to a large rancheria on a stream identified by Bolton (1916, p. 201) as the Arkansas. Here the houses were of grass, and the natives grew plentiful crops. Subsequently, perhaps on the Platte, practically the entire command was annihilated by Indians.

A few years later, in 1601, Juan de Oñate led a force of more than 70 men, with 700 horses and mules, 6 mule carts, artillery, and the usual servants and camp followers eastward from New Mexico into the plains (Bolton, 1916, p. 250). The point of departure was San Gabriel, on the right bank of the Rio Grande between Santa Clara pueblo and the mouth of Chama River. The route led across the Pecos and Gallinas Rivers, and down the Canadian. One hundred eleven leagues from San Gabriel they left the river because of sand dunes, turning northward up a small stream which led them into the plains covered with bison. Two small streams flowing eastward were followed for a time. Then, like Coronado's army, they lost their bearings, and wandered off their course. Eventually, at more than 200 leagues from San Gabriel, they encountered a camp of Escanjaques, and 12 leagues farther on, after fording a large east-flowing stream, found a great rancheria of Indians dwelling in grass houses.

This rancheria, to judge from the map and narrative, lay on both banks of a good-sized river flowing from the north into the large one crossed by Oñate. It consisted, according to the Spaniards, of 1,200 houses, all round in form, and built of poles covered with grass. Much fine maize was found, and in addition there were fields of beans and gourds. The Spaniards were informed that large numbers of people like these lived farther up the river. Owing to hostilities between his Indian "allies," the Escanjaques, and the natives of the grass houses, the expedition was unable to extend its explorations.

Additional information based on the subsequent testimony given by members of the Oñate expedition in Mexico City in 1602 has been presented by Scholes (Scholes and Mera, 1940, p. 274). Here we are told that "the huts were grouped in barrios of 30 or 40, the huts being about 30 to 40 paces apart, and . . . . the barrios were separated by two or three hundred paces. Surrounding each hut was a small cultivated plot where maize, beans, and calabashes were raised." The Indians wore clothing of deer and bison skins, had no textiles, used metates, made pottery of brown clay and small dishes from calabashes, and apparently possessed a few small dogs.

Scholes says this "gran poblacion was undoubtedly a Quivira settlement, located in the same region as the Quiviras whom Coronado visited in 1541" (op. cit., p. 274), and notes that the details of material culture are essentially the same in both cases. Bolton (1916, p. 260) suggests that the large rancheria seen by Oñate was either on lower Cow Creek or else on Little Arkansas River. Unfortunately, both of these localities are now occupied by cities of some size—the former by Hutchinson, the latter by Wichita. It is extremely improbable, therefore, that archeology will ever be able to throw any light on the aboriginal occupancy of either place.

If Oñate actually reached the Arkansas Valley, I venture to suggest a third possibility—the Walnut River east and northeast of Arkansas City. This enters the Arkansas River from the north at a point where the latter flows due east, which accords with Oñate's observations. On the lofty bluffs overlooking the Walnut from the east, on land now occupied by the Arkansas City Country Club, is a large group of mounds—probably the largest and best-preserved in Kansas. From a cache pit beneath one of the lesser mounds came a Pueblo sherd dated circa 1525-1650, along with locally made pottery and other artifacts virtually identical with materials in Rice and McPherson Counties. Closely similar remains, with middens and cache pits, are scattered north and south from this mound group along the Walnut for a distance of at least 3 miles, possibly more. Across the river, along an abandoned channel of the Walnut, are to be found a series of habitational areas covering an equal or greater stretch of ground. Here, too, cache pits yielded Puebloan glaze-paint sherds of the 1525-1650 periods, together with specimens like those on Cow Creek and Little Arkansas River. If several of these neighboring communities were occupied contemporaneously they would have given the visitor precisely the impression received by Oñate's men—a great rambling settlement made up of barrios or groups of huts with a fine river flowing through their midst. Moreover, it is clear that farther to the north up the Walnut, as well as up the Arkansas and its branches, there were other settlements whose inhabitants must have lived in essentially identical manner. In other words, the geographical observations of Oñate tally nicely here; and so far as archeology affords any check, the inhabitants of these Walnut Valley sites followed a subsistence economy and practiced arts and industries like those recorded by him in the Quiviran rancheria of 1601.

I am acutely conscious of the fact that the incomplete record left by Oñate, especially as regards his route from the Canadian, imposes several difficulties on present final acceptance of the Walnut River locality. As with Coronado's explorations, the movements of Oñate were not recorded in a detailed day-by-day journal. We know that Oñate left San Gabriel on June 23 and returned on November 24 (Bolton, op. cit., p. 265), a total elapsed time of 154 days, and that the return trip from Quivira required 59 days. How much of the remaining 95 days was spent in exploring Quivira, and how long it took the presumably slow-moving expedition to reach the province is not stated. Neither the narratives nor the map indicate several rivers and a number of creeks which would have been crossed between the Canadian and the Walnut. Some large ravines and broken hills were encountered, but nowhere did the terrain offer any serious obstacles to easy movements of the army's carts. The Quiviran settlement, as previously stated, was about 220 leagues from San Gabriel, i. e., just about double the distance from San Gabriel to the point where the Canadian was left. If this latter point was in the Texas Panhandle (Donoghue, 1936, p. 11) or immediately east of it (Bolton, op. cit., p. 255), the expedition would have been about halfway, in an airline, to the Walnut River.[7]

[7] Donoghue has published several papers (1929, 1936, 1940) arguing that neither Coronado nor Oñate ever marched beyond the Staked Plains and Texas Panhandle. He deals harshly with the "Quivira-in-Kansas idea." The ravine "like those of Colima" he identifies with Palo Duro Canyon, the river below Quivira with the Canadian, and Quivira with the Canadian Valley, Wolf Creek,

SUMMARY AND CONCLUSIONS

Scattered throughout a wide area in central and southern Kansas, chiefly in the Arkansas basin but extending also into the Smoky Hill and upper Cottonwood drainages, are numerous aboriginal village sites. Preliminary archeological investigations show that these were

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and their tributaries. Since I am not intimately familiar with the topography of the Texas Panhandle, I cannot fairly judge whether Palo Duro and Tule Canyons are the only ones in the northern or central part of the State that could possibly qualify as the barrancas mentioned by Castañeda. I am unable to accept Donoghue's categorical assertion that the rivers named or specifically mentioned in the sixteenth-century narratives are the only ones the expedition could have seen. If such streams as the Canadian and Cimarron carried no more water in June of 1541 than they have in recent summers, their crossing would probably have been quite uneventful and might not have lingered long in the memory of the Spaniards.

I have already shown that there are difficulties in the way of accepting the relatively short distance (ca. 250 miles) from Palo Duro Canyon to the Arkansas as sufficient to occupy Coronado's band of horsemen for 30 or 35 days. It is infinitely more difficult—and for me impossible—to believe that 30 days would have been required to travel the 50 or 60 miles from Palo Duro Canyon to the Canadian where it turns toward the northeast. Jaramillo says the marches were not long, but are we to believe that they averaged under 2 miles a day? Moreover, if the settlements of Quivira were no farther from the barrancas than Wolf Creek is from Palo Duro Canyon (circa 120 miles), Coronado could easily have discovered them and sent back for the army which waited 15 days at the barranca for word from him.

In a footnote Donoghue (1936, p. 8) observes that "The latest support to the Quivira-in-Kansas theory is based on flimsy evidence supplied by 'certain spots of extremely rich soil' identified as the archeological remains of grass lodges presumably standing at the time of Coronado's alleged visit and occupied by the Quiviras or Wichita!" Moorehead (1931) is cited in this connection but no page reference is given and I am unable to determine just where these "certain spots" are located. If, as I suspect, they were in central Kansas, it is probable that the passage refers to some of the refuse mounds which characterize the Rice and McPherson County sites. I consider the evidence collected from these spots by the United States National Museum expedition of 1940 far from flimsy, and as constituting strong support for the position toward which this paper is making. As for the ruins along Wolf Creek and elsewhere in the Texas Panhandle, to which Donoghue (op. cit., p. 9, footnote) calls attention, limited archeological investigations have shown that they comprise chiefly rectangular adobe or adobe-and-slab walled structures (Moorehead, op. cit., pp. 94, 131 ff.) in no wise comparable to the grass houses seen by Coronado and Oñate in Quivira.

The Quivira-in-Texas theory is tenable only if we follow Donoghue (1936, p. 7) in his almost complete disregard for the number of days or the distance in leagues which Coronado, Oñate, and their followers estimated they traveled. I do not believe that the observations in the documents concerned can be swept aside in such arbitrary fashion.

the habitat of a widespread and numerous semisedentary people practicing a maize-bean-squash horticulture, as well as hunting and gathering. There is a striking uniformity in the pottery and other cultural remains from sites in Rice, McPherson, Marion, Butler, and Cowley Counties. The discovery of chain-mail fragments, glass beads, an iron ax blade, etc., indicate that the sites were inhabited into or during a very early period of white contact; turquoise, glaze-paint sherds, and obsidian are evidence of trade relations with Puebloan groups in the Rio Grande area. Moreover, glaze-paint sherds from widely sepaated sites in Rice and Cowley counties have been identified with wares produced on the Rio Grande between circa 1525 and 1650.

As I view the archeological evidence and its geographical setting the conviction is strong that the Quivira of the sixteenth- and early seventeenth-century Spanish documents and the central-Kansas archeological sites were the habitat of one and the same people. I cheerfully admit that the final word on the routes of Coronado and Oñate has yet to be written. Meanwhile, and until convincing evidence to the contrary is adduced, including archeological and ethnological as well as documentary data, I am of the opinion: (1) That Coronado's entrada into the province of Quivira probably took place in the present Rice-McPherson County locality; (2) that Oñate's visit to Quivira 60 years later possibly took place on the Walnut River near the present Arkansas City, Kans.; (3) that while the exact limits of Quivira in Kansas cannot now be set up, the heart of the province (fig. 1) lay north and east of the Arkansas and south of the Smoky Hill, extending from Rice, or possibly Barton, County east through McPherson and Marion Counties, thence south through Harvey, Butler, and Cowley Counties, to or beyond the Kansas-Oklahoma State boundary.

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WICHITA GRASS LODGE

From a photograph in the United States National Museum collections, made by Lenny and Sawyer, Purcell, Indian Territory.

a

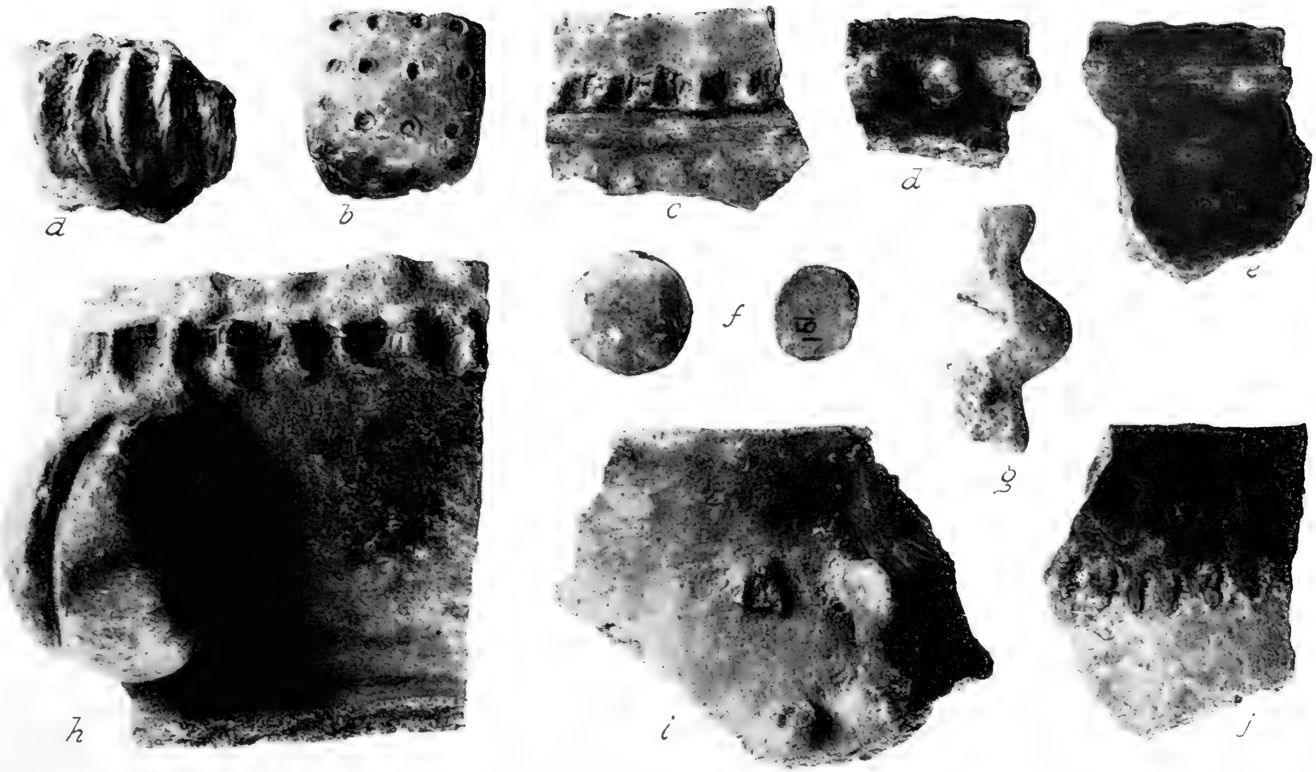
b

RESTORED VESSELS FROM KANSAS

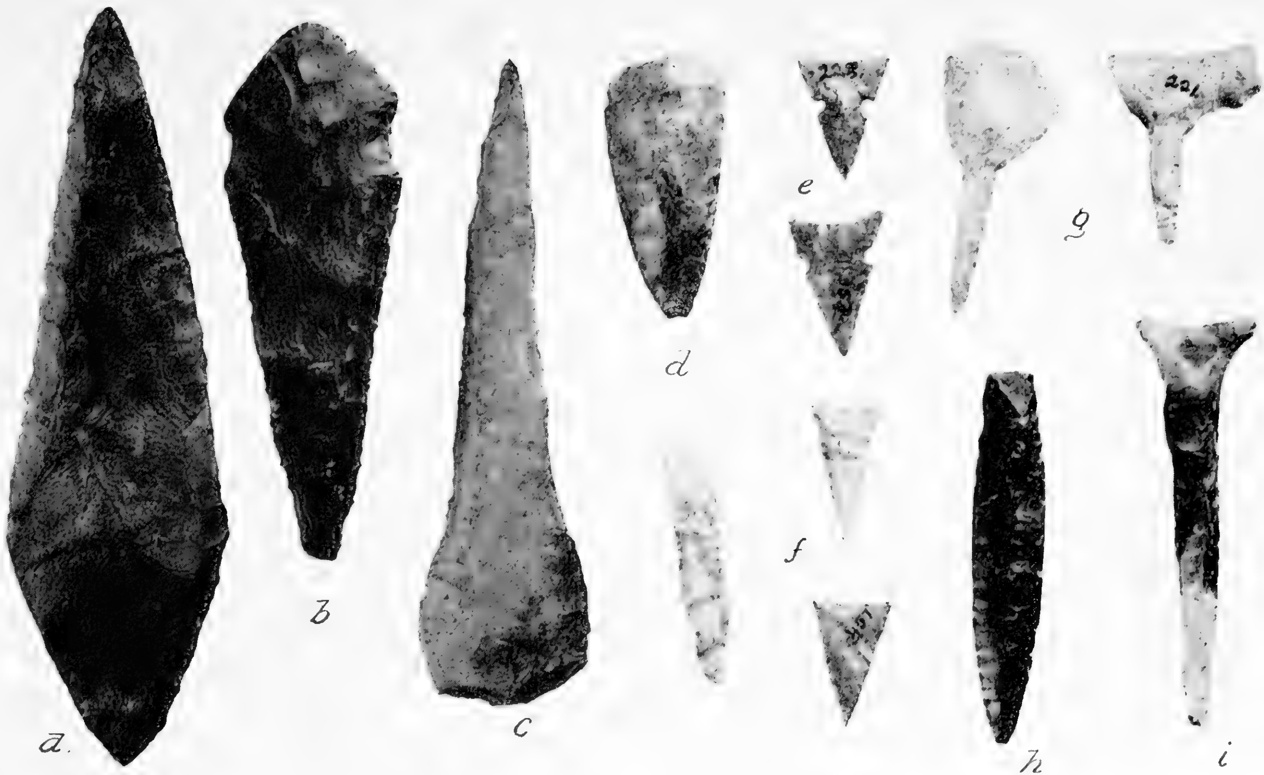
a, from Arkansas City Country Club site, Cowley County, height 11 inches; *b*, from Tobias site, Rice County, height $9\frac{1}{2}$ inches.

MISCELLANEOUS SPECIMENS FROM TOBIAS SITE, RICE COUNTY, KANS.

Height of *a*, 8¼ inches.

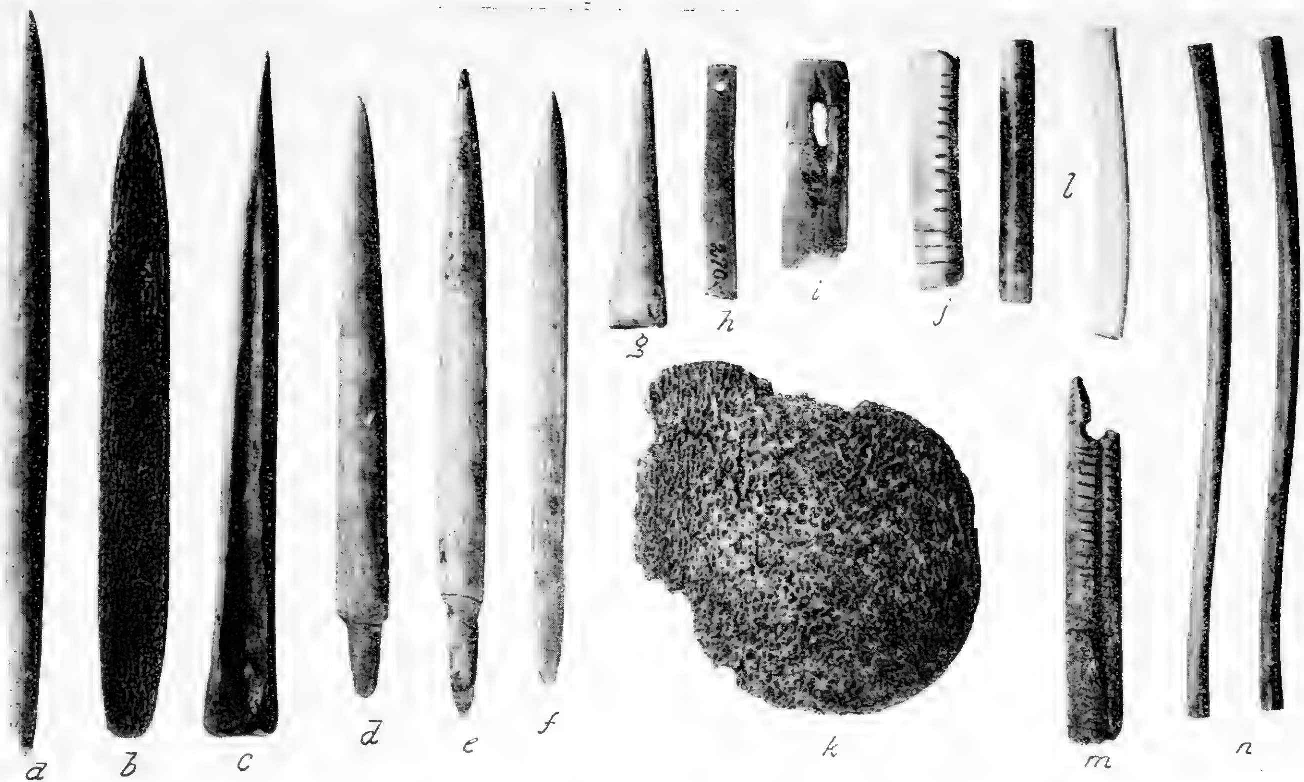


RIMSHERDS, VESSEL HANDLES, AND SHERD DISKS FROM TOBIAS SITE, RICE COUNTY, KANS.

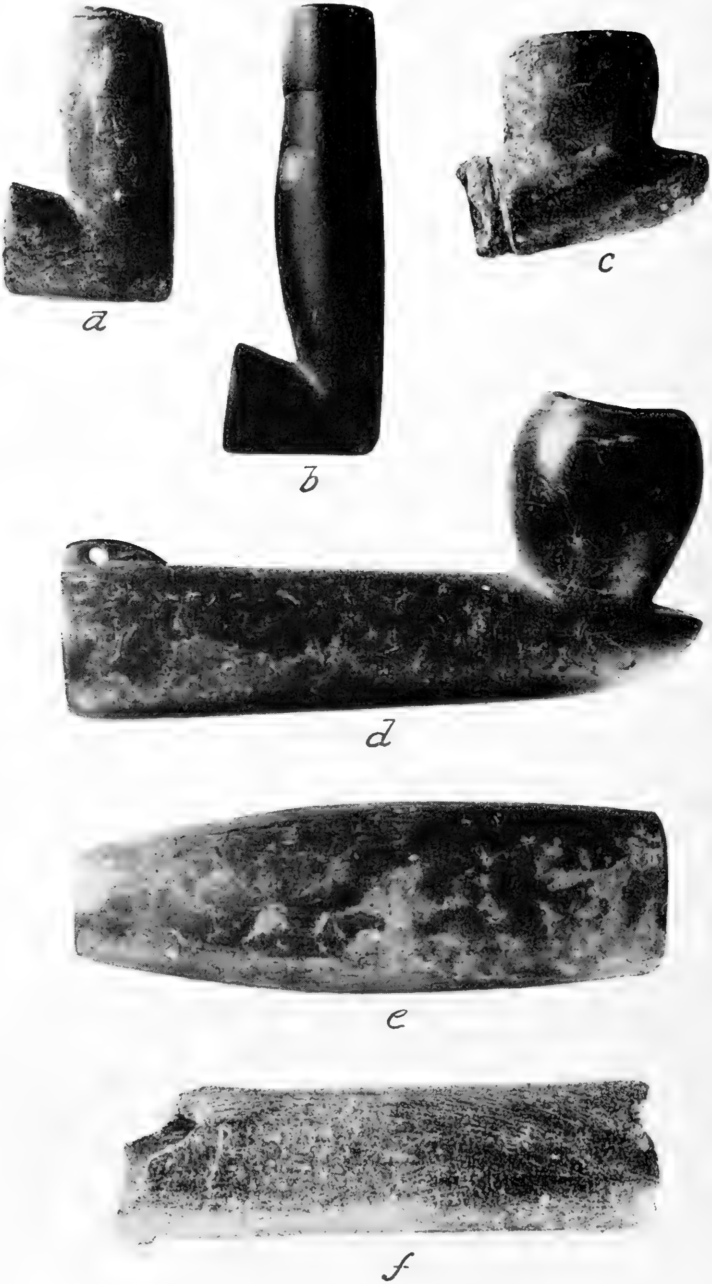


Chipped Stone Artifacts from Various Sites in Rice and Cowley Counties, Kans.

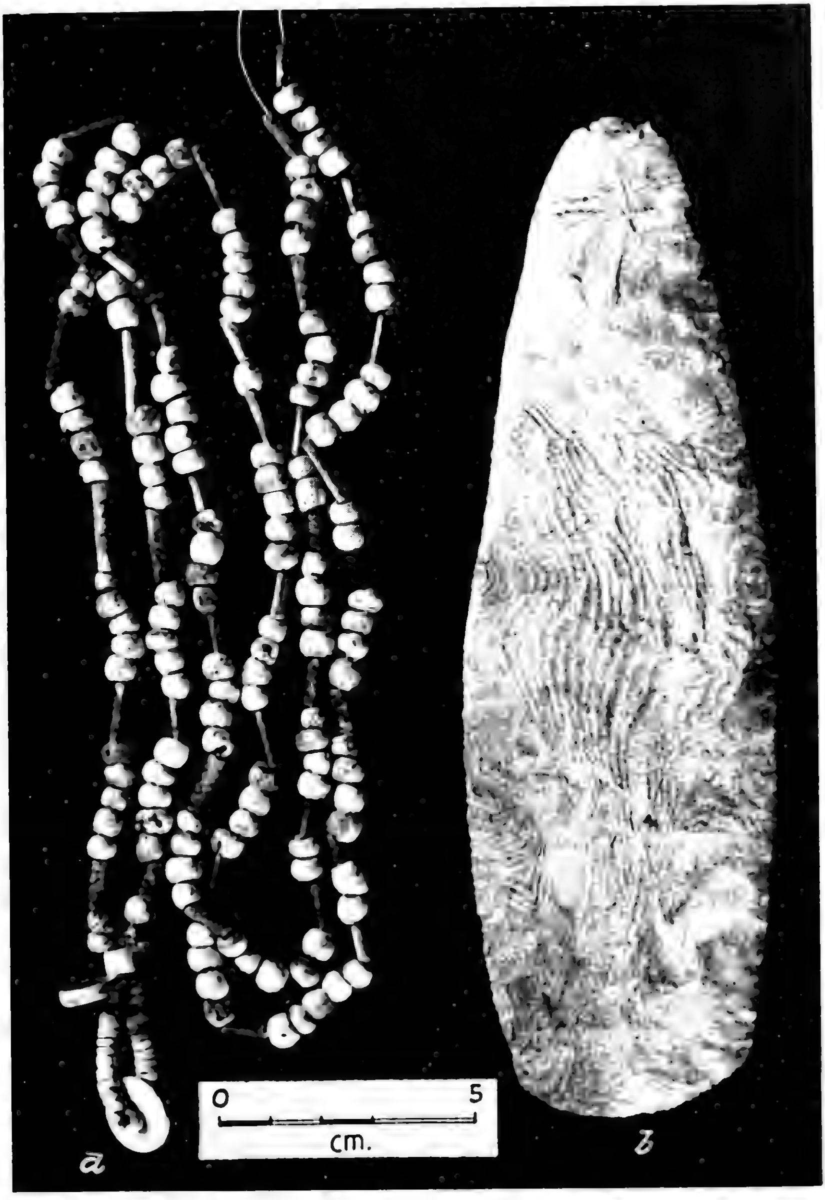
BONE ARTIFACTS FROM THE TOBIAS SITE, RICE COUNTY, KANS.



BONE ARTIFACTS FROM SITES IN RICE COUNTY, KANS.

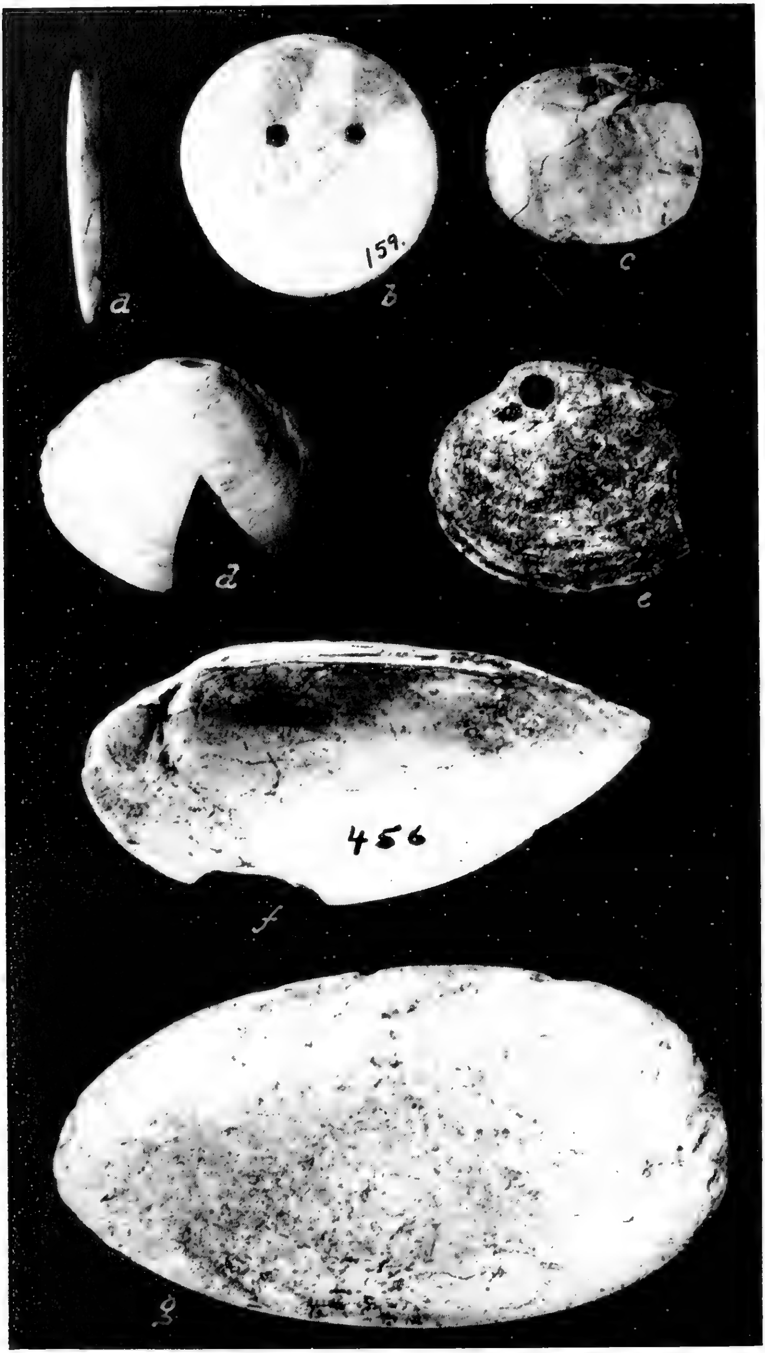


PIPES FROM TOBIAS SITE, RICE COUNTY, KANS.



ARTIFACTS FROM TOBIAS SITE, RICE COUNTY, KANS.

a, necklace of blue glass and bird-bone beads, with turquoise and shell pendants; *b*, blade of banded Florence flint, possibly from aboriginal chert quarries near Maple City, Kans., or Hardy, Okla.



SHELL ARTIFACTS FROM VARIOUS SITES IN RICE AND COWLEY COUNTIES, KANS.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 101, NUMBER 8

BEES OF THE FAMILY HYLAEIDAE FROM THE ETHIOPIAN REGION

BY
T. D. A. COCKERELL
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INTRODUCTION

The bees now recorded are a part of a collection received from the British Museum, to which they will be returned after the war. The hylaeid bees, with short tongues, are considered primitive, and yet are differentiated into numerous groups showing striking modifications. As V. B. Popov, of Leningrad, has recently set forth in some detail, the holarctic species can be divided into a considerable number of groups or subgenera. In Australia and Africa, however, there is much more diversity, and no one has questioned the recognition of several Australian genera, the characters of which are (with the exception of some more recently described) set forth by Meade-Waldo in Genera Insectorum, 1923. However, the species usually referred to *Prosopis* or *Hylaeus* are themselves diverse and will no doubt eventually be split up into a series of genera. J. C. Bridwell (Proc. Hawaiian Ent. Soc., vol. 4, June 1919) has made a beginning of this as regards the African species, recognizing a new genus *Nothylaeus* for the species *heraldicus, junodi, braunsi, rubrifacialis, sansibaricus, nyassanus, binotatus, magrettii, gigas, peringueyi,* and *yoruba*. *Anylaeus* is a new subgenus of *Nothylaeus* for *aberrans* and *dentiferellus*. *Metylaeus* is a new genus for *cribratus, catalaucoides,* and *scutispina*. *Deranchylaeus* is a new subgenus of *Hylaeus,* including the rest of the species of the Ethiopian region. Thus while in the related family Colletidae true *Colletes* is well represented in South Africa, the Ethiopian region has a peculiar hylaeid fauna of its own, although it is not so distinct as that of Australia.

In working over these bees, I have not found it easy to classify them into genera and subgenera and so have recorded as *Hylaeus* numerous species which do not belong to that genus in the restricted sense. Following and extending the methods of Bridwell, some student should reclassify the Hylaeidae of the world, including the numerous African species which were unknown to Bridwell. This undertaking is not now possible, owing to the disturbed condition of the world, and in any case it will be difficult to assemble in any one place a sufficient collection for the purpose.

I give a list of the names proposed for African species (excluding those of the Palaearctic portion), and a key to the separation of the species discussed in this paper.

NAMES PROPOSED FOR AFRICAN SPECIES

Those marked with an asterisk are described or recorded in the present paper.

aberrans Bridwell, 1919
abjunctus Cockerell, 1936
absonulus Cockerell, 1936
albonasatus Strand, 1912
alfkeni Friese, 1913
  xanthopus Alfken, 1914
**ameliae*, new species
arnoldi Friese, 1913
**aterrimus* Friese, 1911
  quinquedentatus Friese
atriceps Friese, 1911
atriceps major Strand, 1912
bequaertianus Bridwell, 1919
bevisi Cockerell, 1917
binotatus Alfken, 1914
braunsi Alfken, 1905
braunsi fumata Strand, 1912
braunsi nigricans Friese, 1913
buyssoui Vachal, 1899
**capicola* Alfken, 1914
catalaucoides Bridwell, 1919
clavigera Cockerell, 1936
cribratus Bridwell, 1919
**curvicarinatus* Cameron, 1905
  robertianus Cameron, 1906
**dentiferellus* Strand, 1912
dregei Strand, 1912
**flaviscutum* Alfken, 1914
  vau Cockerell, 1936
fortis Cockerell, 1936
gabonicus Vachal, 1899
gaullei Vachal
gigas Friese, 1911
graaffi Cockerell, 1936
haygoodi Bridwell, 1919
heraldicus Smith, 1853
  abyssinica Alfken, 1905
  rubriplagiatus Cameron, 1905
heraldicus maculipes Cockerell, 1936
heraldicus rufipictus Strand, 1912
**immarginatus* Alfken, 1914
**junodi* Friese, 1911
  rufipedoides Strand, 1911
**junodi montacuti*, new variety
**junodi rhodesicus*, new subspecies
kasindensis Cockerell, 1936
krebsianus Strand, 1912
leucolippus Friese, 1913
libericus Cockerell, 1936
lightfooti Bridwell, 1919
lineaticeps Friese, 1913
**magnificus*, new species
magrettii Vachal, 1892
**melanosoma* Cockerell, 1920
**microstictus*, new species
**namaquensis*, new species
**neavei*, new species
nyassanus Strand, 1912
ogilviei Cockerell, 1932
**perater* Cockerell, 1936
perdensus Cockerell, 1936
peringueyi Bridwell, 1919
**pondonis*, new species
promontorii Meade-Waldo, 1923
  longulus Friese, 1913 (preoccupied)
**proteae*, new species
punctiferus Cockerell, 1936
reditus Cockerell, 1936
rhodognathus Cockerell, 1936
rubrifascialis Strand, 1912
rugiceps Friese, 1921
rugipuncta Alfken, 1914
sanctus Cockerell, 1936
sansibaricus Strand, 1912
scutispina Alfken, 1914
simplex Bingham, 1923
  simplior Meade-Waldo, 1923
**simpsoni*, new species
**simulans*, new species
**subfortis*, new species

sublucens Cockerell, 1936
**subreditus,* new species
tenuis Alfken, 1914
tenuis dominae Cockerell, 1936
tinctulus Cockerell, 1932
tinctulus extensicornis Cockerell, 1936
uelleburgensis Strand, 1912
ugandicus Cockerell, 1939
**umtalicus* Cockerell, 1936
varians Cockerell, 1936
**xanthostoma* Alfken, 1914
yoruba Bridwell, 1919

KEY TO SPECIES DISCUSSED IN THIS PAPER

Abdomen at least partly red....................1
Abdomen not at all red....................10
1. Clypeus yellow or yellowish white, the lateral margins sometimes dark......2
Clypeus with middle third, or not much more, yellow....................7
2. Scutellum entirely black; legs and tegulae red..........**neavei,** new species
Scutellum with light spots....................3
3. Small species; face marks yellowish white; postscutellum with two teeth...4
Larger species; face marks yellow; postscutellum unarmed................5
4. First tergite almost entirely red (Okahandja)..........**dentiferellus** Strand
First tergite black, red only at sides (Durban)..........**dentiferellus** Strand
5. Supraclypeal mark a little broader than long
junodi rhodesicus, new subspecies, female
Supraclypeal mark much longer than broad....................6
6. Lower end of lateral marks contiguous with clypeal yellow
junodi rhodesicus, new subspecies, male
Lower end of lateral marks well separated from clypeal yellow
junodi Friese, male
7. Mesonotum red; no light spots on scutellum...........**simpsoni,** new species
Mesonotum black 8
8. Second abdominal tergite red; sides of clypeus red
junodi rhodesicus, new subspecies
Second tergite black, the first red....................9
9. Supraclypeal mark higher than broad.......**junodi** v. **montacuti,** new variety
Supraclypeal mark not higher than broad....................**junodi** Friese
10. Abdomen steel blue....................**magnificus,** new species
Abdomen black 11
11. Face with three light stripes....................12
Face all light....................15
Clypeal region and mouth red....................**xanthostoma** Alfken
Clypeus black, or with a minute light spot....................27
12. Supraclypeal mark present; larger species....................13
Supraclypeal mark absent; smaller species....................14
13. With paired spines on abdomen....................**aterrimus** Friese
Without such spines....................**pondonis,** new species
14. Clypeus with a large cuneiform white mark................**capicola** Alfken
Clypeus with only a light stripe....................**capicola** Alfken
15. Larger species, about 10 mm. long....................16
Much smaller 18
16. Lateral face marks elongate and attenuate above; face pale yellow
fortis Cockerell
Lateral face marks shorter, not attenuate above; face chrome yellow.....17

17. A conspicuous black stripe at each side of clypeus......**ugandicus** Cockerell
Only a black dot at each side of clypeus..............**subfortis,** new species
18. Supraclypeal mark present; scutellum with two light marks
ameliae, new species
Supraclypeal mark present; scutellum without light marks..............19
Supraclypeal mark absent; scutellum without light marks............. 23
19. Larger; face orange...20
Smaller; face white or very pale yellow..................................21
20. Upper level of orange deeply excavated at insertion of antennae
namaquensis, new species
Upper level of orange nearly even.....................**umtalicus** Cockerell
21. Upper extension of lateral marks broad; flagellum bright red beneath
curvicarinatus Cameron
Upper extension of lateral marks slender; flagellum duskier red..........22
22. Wings distinctly dusky............................**subreditus,** new species
Wings clear ....**flaviscutum** Alfken (*vau* Cockerell)
23. Light color of clypeus extending above inner level of lateral marks, simulating a supraclypeal mark.......................**immarginatus** Alfken
Light color of clypeus not so extending.................................24
24. Light color of clypeus level with inner corners of lateral marks
immarginatus Alfken
Light color of clypeus not thus level....................................25
25. Legs, at least basitarsi, largely yellow; very near *H. varians,* but clypeus much shorter (Port St. John)................................species
Legs not at all yellow...26
26. Smaller, face narrower; upper end of lateral marks slender (Durban, F. Muir) ....species
Larger, face broader (Mossel Bay, Turner)........................species
27. Face black, with a large triangular light mark at each side
namaquensis, new species, female
With large lateral marks on upper part of face, and a triangular supraclypeal mark ....**proteae,** new species
Lateral face marks linear, punctiform, or absent......................28
28. Face entirely black in both sexes; scape of male swollen (Abyssinia to S. Rhodesia) ....**perater** Cockerell
Clypeus with a large shining pit (female)............................29
Clypeus without such a pit...30
29. Collar with conspicuous light margin.............**microstictus,** new species
Collar all black; face marks very weak.............**subreditus,** new species
30. Smaller; face marks linear, well developed............**flaviscutum** Alfken
Larger; face marks reduced to small spots, or absent; wings dusky
melanosoma Cockerell

There is a residue of small dark-faced females, collected by Turner, as follows:

Lateral marks linear, well developed.....................................1
Lateral marks reduced to small spots or absent..........................3
1. Collar black (as in *H. flaviscutum*) (Swellendam).....................sp.
Collar yellowish white...2

2. Tubercles partly white (Port St. John, Turner, 9) .... sp.
   Tubercles black (Katberg) (Turner, 7) .... sp.
3. (Smaller than *H. melanosoma*, and with clear wings)
   Front dull (Katberg; Mossel Bay) .... sp.
   Sides of front shining (Worcester; Matjesfontein) .... sp.

The unnamed species in this key are, with the exception of the last two, represented by single specimens, and they are best left unnamed for the present. They are all small, without striking characters.

NOTHYLAEUS SUBFORTIS, new species

Male.—Length about 10.5 mm.; robust, black, with no red, and no light marks on scutellum; labrum black, mandibles obscurely reddish at end; face pale lemon yellow, shining, the yellow including clypeus, supraclypeal mark (which is hat-shaped, narrowed and truncate, not at all notched, above), and lateral marks, which form broad triangles with the base on orbit, and the inner sides about equal; frontal keels strong, somewhat arched outward; antennae entirely black; mesonotum dull, very coarsely punctured; scutellum moderately shining, with very large punctures, and a strong median groove; area of metathorax with very coarse irregular rugae; pronotum with two widely separated yellow spots above, and a large part of tubercles yellow; tegulae black; wings dilute fuliginous; basal nervure falling short of nervulus; first recurrent joining first cubital cell some distance from end, second recurrent going very slightly beyond outer intercubitus; legs black, the front tibiae and small joints of hind tarsi a little reddish; abdomen very finely punctured, the apical margin of first tergite, and all of second, shining; no hair bands; third sternite with a strong curved transverse callus.

East Africa: 150-200 miles west of Kambove, 3,500-4,500 feet, October 15, 1907 (S. A. Neave).

Closely allied to *N. fortis* Cockerell, but differing by the broader, more shining face, its color more orange, the lateral face marks less attenuated above; the mesonotum more robust and more coarsely sculptured. *N. fortis* was described from the Belgian Congo, but Neave took three in the Bugoma Forest, Uganda, 3,700 feet, December 1-5, 1911; and in the Mabira Forest, Chagwe, Uganda, 3,500-3,800 feet, July 1911, he took one *N. fortis* and one *N. ugandicus* (Cockerell). I described *N. ugandicus* under *Hylaeus*, and suggested at the time that *N. fortis* should also be so referred. As more species come to light, it is hard to define the genera precisely, but certainly those insects are nearer to *Nothylaeus* than to typical *Hylaeus*.

NOTHYLAEUS JUNODI (Friese)

Turner took both sexes at Mossel Bay and Queenstown, and a female at Ceres. In one of the Mossel Bay females the clypeal mark is broadened at the lower end.

NOTHYLAEUS JUNODI RHODESICUS, new subspecies

Length about 7 mm.; head and thorax dull black, the face largely yellow; first tergite red, second obscurely red in female, and red at extreme base in male; two transverse yellow spots on scutellum; legs red.

Female (type).—Labrum and mandibles dull red; face marks dull yellow; clypeus yellow with a broad red band down each side; supraclypeal mark large, somewhat broader than long; lateral face marks running about halfway up sides of front, the upper end greatly narrowed; antennae red, the scape with a yellow line in front, flagellum dusky above; vertex dull, but a shining spot above each eye; pronotum red, including tubercles, but collar yellow; scutellum shining, but mesonotum dull; area of metathorax large, coarsely sculptured only at basal middle; tegulae red; wings clear, stigma and nervures brown; basal nervure falling short of nervulus; first recurrent nervure joining first submarginal cell some distance before end; first and second tergites with a band of white pubescence on each side of apical margin. The yellow spots on scutellum are separated by a linear interval.

Male.—Similar but more slender; clypeus pale yellow with a black bar on each side, failing at lower end, so that the clypeal yellow meets the lateral marks; supraclypeal mark much longer than broad; scape entirely red; abdomen without tubercles, the venter shining.

South Rhodesia (Matabeleland); Lonely Mine (H. Swale).

Both sexes taken June 1, the type male, June 4, 1913. I separated this from *N. junodi* (Friese) as follows:

Clypeus yellow except at sides..1
Clypeus with middle third, or not much more, yellow.....................3
1. Supraclypeal mark a little broader than long
junodi rhodesicus Cockerell (type), female
Supraclypeal mark longer than broad.....................................2
2. Lower end of lateral marks contiguous with clypeal yellow
junodi rhodesicus Cockerell, male
Lower end of lateral marks well separated from clypeal yellow
junodi (Friese), male
3. Second tergite red; sides of clypeus red..**junodi rhodesicus** Cockerell, female
Second tergite black; first red..4

4. Supraclypeal mark higher than broad (Montagu)
junodi (Friese), male, var. *montacuti,* new variety
Supraclypeal mark not higher than broad.................................5
5. Clypeal mark greatly broadened at lower end (Mossel Bay)
junodi (Friese), female
Clypeal mark not broadened at lower end (Queenstown, Ceres, Mossel Bay) ....**junodi** (Friese), female

The Montagu *N. junodi* male, taken by Turner in September, has the face marks cream color, and the clypeus with a broad black band down each side; the marks on scutellum are rather widely separated. The third sternite of the abdomen has a strong transverse thickening, of which there are only faint indications in the other *N. junodi.*

N. junodi was originally based on the female, from Shilouvane in the Transvaal. Strand's *N. rufipedoides* (not *rufipedioides,* as Bridwell has it) appears to be the same, so far as the description shows. He had males from "Kapland" and a female from Langenburg, Lake Nyasa.

NOTHYLAEUS DENTIFERELLUS (Strand)

This was described from a male from Delagoa Bay. The first abdominal segment is described as red, with the sides of the dorsum blackened. Three taken by Turner at Okahandja, on the opposite side of the continent, have the middle of the dorsum blackened posteriorly. One from Durban, Natal, July 31, 1916 (C. M. Barker), has the first tergite black except at extreme sides, where it is red. More material may suggest the recognition of one or more subspecies.

HYLAEUS UMTALICUS (Cockerell)

Nyasaland; Mlanje, May 24, 1913, one male (S. A. Neave).

This was described under *Nothylaeus,* but the mandibles are not as in that genus. The present specimen differs from the type in the clearer wings, and the first recurrent nervure ending some distance before the end of first cubital cell.

HYLAEUS AMELIAE, new species

Male.—Length about 4 mm., anterior wing a little over 3 mm.; black, with face, collar (interrupted in middle), tubercles, and two transverse marks on scutellum creamy white; clypeus long; supraclypeal mark well developed, subquadrate, extending between antennae; lateral face marks broad above, ending in a point on orbital margin halfway up front; antennae ferruginous, dusky above; scape pyriform; a smooth shining band at outer side of lateral ocelli;

mesonotum dull, very coarsely punctured; area of metathorax very coarsely sculptured, the ridges shining; tegulae pale red, with a white spot; wings hyaline, faintly dusky, stigma and nervures brown; basal nervure falling a little short of nervulus, first recurrent nervure joining first cubital cell not far from end; legs red with a blackish suffusion, front legs with a large white mark on basal half, and the basitarsi white; abdomen mainly dull, but first tergite polished; hind margins of first two tergites with fringes of white hair, interrupted in middle.

Portuguese East Africa: Porto Amelia (F. V. Beste).

Perhaps to go in *Nothylaeus,* but not a typical member of that genus. It will be known by the very small size, wherein it resembles *H. melanosoma* (Cockerell), but the antennae are not as long as in that species, and the markings are very different. From various small species it is known by the spots on the scutellum. The microscope shows that the supraclypeal mark is trilobed at upper end, and the mandibles are red. The trilobed upper end of supraclypeal mark recalls *H. dentiferellus* (Strand).

HYLAEUS MICROSTICTUS, new species

Female.—Length nearly 7 mm.; black, including legs, but with white markings as follows, rather broad bands along inner orbits, the lower end about level with lower end of eye, the upper rather less than halfway up front, strong band on collar, interrupted in middle, and large spot on the otherwise black tegulae; tubercles black, the margin ciliate with short white hairs; flagellum obscure reddish beneath; face broad; clypeus with a shining transverse well-defined semilunar depression, and on each side of it an obtuse longitudinal ridge; front dull; vertex a little shining, well punctured; mesonotum and scutellum dullish (not at all polished), very closely and minutely punctured; metathorax entirely dull, the area rugulose; wings dusky, stigma and nervures brown; basal nervure meeting nervulus; first recurrent ending some distance before end of the very long first cubital cell; abdomen shining, with a short band of white hair sublaterally on each side of margin of first and second tergites; first tergite very finely punctured.

Cape Province; Mossel Bay, March-April 1930, and October 26-31, 1933, three specimens (R. E. Turner, 7, in part).

Belongs to the *H. dregei* group, and is easily distinguished by the finely punctured first tergite, white band on collar, dusky wings, and black tubercles. *H. lineaticeps* (Friese), of which I possess only the male, has yellow markings, and the thorax above evidently shining. The female *H. lineaticeps* has the collar entirely black.

HYLAEUS CURVICARINATUS (Cameron)

Cape Province: Swellendam, November 1933, 3 males (R. E. Turner).

HYLAEUS NEAVEI, new species

Male.—Length about 9 mm.; robust, black, with the face dull pale orange, and the sides and base of first tergite broadly red; the tubercules, legs, extreme apex of abdomen, and subapical region beneath, also red; tegulae shining clear red; wings clear hyaline, stigma dilute brown. Face broad; supraclypeal mark quadrate, broader than long; lateral marks attenuate above, coming to a sharp point not on orbit; antennae red, the flagellum dusky above; mesonotum dullish, coarsely punctured; scutellum shining between the large punctures, contrasting with mesonotum; area of metathorax coarsely wrinkled, but shining; posterior face of metathorax with a conspicuous shining channel in middle; basal nervure falling short of nervulus; first recurrent meeting intercubitus; second recurrent joining second cubital cell a little before end; abdomen dullish; first tergite with an apical band of white tomentum on each side; third sternite with a pair of sublateral ridges; sixth red, with prominent corners.

East Africa: Southeast slopes of Mount Kenya, 6,000-7,000 feet, February 3-12, 1911 (S. A. Neave).

Closely allied to the much smaller *bevisi* (Cockerell), from Natal, but the mesonotum is much more coarsely punctured than in that insect. These bees should perhaps go in *Nothylaeus.*

HYLAEUS MAGNIFICUS, new species

Male.—Length about 9.5 mm.; rather slender, with long antennae; head, thorax, abdomen, femora, and tibiae bright steel blue, or perhaps better described as purple; mouth parts typical for *Hylaeus;* clypeus with a large conical creamy-white mark, varying much in size; antennae black, the flagellum obscurely brownish beneath; thorax without light markings; mesonotum dull and finely punctured; scutellum more shining, but still finely punctured; area of metathorax large, poorly defined, appearing rugulose; tegulae purple; wings variably dusky, sometimes quite dark; basal nervure falling a little short of nervulus; first recurrent nervure joining first cubital cell a variable distance from end; abdomen shining, without hair bands; venter simple.

East Africa: East foot and slopes of Aberdare Mountains, 7,000-8,500 feet, February 24-27, 1911 (S. A. Neave).

Very distinct by its purple color, which recalls some of the Australian Hylaeidae. Four specimens were collected.

HYLAEUS ATERRIMUS (Friese)

Pondoland: Port St. John, two females, October 1923, one male January 1924. (R. E. Turner, 3).

One female is labeled "on *Protea,* 1,200 feet." I have female *H. aterrimus* from Bulawayo and Hope Fountain, South Rhodesia, from the Rhodesia Museum.

HYLAEUS PONDONIS, new species

Male.—Length about 7 mm.; in most respects exactly like *H. aterrimus,* but less robust; the third sternite with a strong dentiform process in the middle, but the paired processes, above and below, entirely lacking; pale clypeal band very slender, its upper end not nearly as wide as base of supraclypeal mark; lateral face marks more slender above; scutellum more shining.

Pondoland: Port St. John, October 1923 (R. E. Turner).

According to Alfken, and I believe correctly, the *Prosopis quinquedentata* Friese is to be considered the true male of *H. aterrimus.* The male which Friese doubtfully referred to *H. aterrimus* is probably *H. pondonis.* But it will be noticed that at Port St. John, Turner took female *H. aterrimus* and male *H. pondonis* in October; male *aterrimus* (agreeing with *Prosopis quinquedentata*) in January. Is it possible that we have two species, easily separated in the male, but alike in the female sex?

HYLAEUS CAPICOLA (Alfken)

Male.—About 4.5 mm. long; black, with very long antennae, the flagellum obscurely reddish beneath; eyes large, and orbits strongly converging below; clypeus dull white, with a broad black band down each side; no supraclypeal mark; lateral face marks well developed, but narrow, bandlike, widely separated from clypeal mark; labrum and mandibles black; mesonotum finely punctured, somewhat shining; no light markings on thorax; tegulae black; wings grayish, iridescent; legs black, tarsi brownish, a light stripe on front tibiae; abdomen narrow, shining.

Female.—About 6.5 mm. long; clypeus with a slender median stripe; lateral marks long slender bands, not diverging from orbits; collar yellowish white, and tubercles margined with the same color; first and second tergites with slight marginal hair bands at sides. The flagellum is obscure brown beneath. The stigma is black, and the nervures are dark.

Pondoland: Port St. John, females, January, April, and May, 1924; male, June 1923 (Turner).

The male resembles *H. melanosoma* (Cockerell) closely, differing by the broad black band along each side of clypeus. The female is easily known from *H. melanosoma* by the three stripes on face. Alfken knew only the female.

HYLAEUS SIMPSONI, new species

Female.—Length about 8 mm.; robust, head (including antennae), thorax, abdomen, and legs light ferruginous; face marks dull cream color, as follows: broad median stripe on clypeus, broadest at upper end, supraclypeal mark, broader than long, long but narrow lateral face marks, extending far up sides of front, and a small transverse mark on each side of clypeus near margin, contiguous with the lower end of clypeal mark (which is curved under eye), but not reaching median band; collar pale yellow, but tubercles red; scutellum without light marks; mandibles shining, very broad, the apex sharply pointed but not much elongate; front and mesonotum dull, scutellum shining; postscutellum large; area of metathorax not very large, wrinkled at base; tegulae red; wings hyaline, stigma red; basal nervure falling short of nervulus; first recurrent nervure meeting intercubitus; first tergite with a conspicuous band of white tomentum at each side before margin; broad margins of second and third tergites pallid with fine pubescence.

Gambia: Bathurst, March 3, 1911 (J. J. Simpson).

Perhaps this should go in *Nothylaeus,* but it is not typical of that genus. I wondered whether the uniform red color could be due to immaturity, but there is no evidence of this. Aside from the red color, which is unique, the markings suggest *Nothylaeus junodi* (Friese), though differing in detail; for example, there are light marks on the scutellum of *N. junodi.*

HYLAEUS PROTEAE, new species

Male.—Length 7.5 to 9 mm.; black with no red, and no spots on scutellum; clypeus shining black, with middle of upper part depressed; face marks white; supraclypeal mark triangular, well developed; lateral face marks broad at level of upper end of clypeus, narrowed to an obtuse point above, below abruptly narrowed, and ending in a hooklike point next to upper part of clypeus, or coming to an acute angle below; scape enormous, globose, intense black, shining; flagellum dull orange beneath, black above; mesonotum and scutellum shining, well punctured; area of metathorax strongly wrinkled; collar white, but tubercles black; tegulae black, with a large white spot; wings hyaline, faintly dusky, stigma very dark brown; basal nervure falling short of nervulus; first recurrent nervure meeting intercubitus; legs black; abdomen with first two tergites shining, the third duller; margin of first tergite with white hair at sides; no dorsal tubercles, but third sternite produced into a large (but variable) flaplike structure.

Pondoland: Port St. John, 10 specimens (R. E. Turner).

The holotype is marked "on *Protea,* 1,200 feet," October 1923. All were taken in October, except one in January 1924. Related to *H. aterrimus* (Friese), but differing greatly in the structure of the abdomen. The face markings recall *H. uelleburgensis* Strand.

HYLAEUS NAMAQUENSIS, new species

Female (type).—Length about 6 mm.; black, the face all black except a large broadly triangular mark on each side at level of upper end of clypeus; flagellum red beneath; collar narrowly margined with white, but tubercles black; hind tibiae with a large yellowish-white mark near base; front tibia reddish in front, and with a pale spot at base; second and following tergites with bands of pure white hair. Head broad; clypeus strongly punctured, conspicuously shining at sides; mesonotum and scutellum polished and strongly punctured; postscutellum shining, but metathorax entirely dull; tegulae subhyaline, with a light spot; wings clear hyaline, stigma and nervures brown; basal nervure meeting nervulus; first recurrent nervure meeting intercubitus; abdomen shining, first tergite duller and strongly punctured, contrasting with the second.

Male.—Length about 5.5 mm.; more slender; labrum and mandibles black, but face entirely lemon yellow, with a large and very long supraclypeal mark, and broad lateral marks ending very obtusely about halfway up sides of front; scape with a slight spot at end; basitarsi white, and small joints pale reddish; tubercles black as in the female.

South-West Africa: Aus, January 1930, 11 females, 10 females (R. E. Turner, 10).

Compared with *H. curvicarinatus* (Cameron) the male has the lateral face marks much broader above, and the supraclypeal mark much longer. *H. promontorii* (Meade-Waldo) and *H. alfkeni* (Friese) have the female face all black.

HYLAEUS FLAVISCUTUM (Alfken)

H. vau Cockerell, 1936, is the male of this species.

Turner collected nine females and five males at Aus, December 1929, and a female at Aliwal North, January 1923.

HYLAEUS IMMARGINATUS (Alfken)

Lion's Head, Cape Town, both sexes, May 1920 (Turner).

Two of the males have the light color of clypeus extending above the inner level of lateral marks, thus simulating a supraclypeal mark. Apparently this is only a variety.

HYLAEUS MELANOSOMA (Cockerell)

Pondoland: Port St. John, May, June, July, August, December, 1923 (R. E. Turner).

Described from Durban and Knysna; Port St. John is between these localities.

HYLAEUS PERATER (Cockerell)

This was described from Tshibinda, Belgian Congo, but was also taken in South Rhodesia.

The following description is based on specimens from Abyssinia, and gives details concerning the structure of the male, not given in the original account.

Male.—Length about 5.5 mm., anterior wing 4.7; entirely black, including legs, antennae, and tegulae; wings dilute brownish, clear at base, stigma dark brown; face broad, but eyes strongly converging below; clypeus long, strongly punctured, narrowed above; scape strongly swollen and highly polished; mesonotum minutely punctured, dull, a little shining on disk, and with three short shining lines; scutellum well punctured, shining; postscutellum large, with a few long hairs at each side; area of metathorax with strong wavy rugae; posterior truncation dull, with a cuneiform shining area in middle; basal nervure falling a little short of nervulus; first recurrent joining apical corner of first cubital cell; abdomen dullish, very minutely punctured, with a marginal fringe of white hair, not always present, at sides of first tergite. The black of the abdomen seems to have a slight bluish tint, so slight as to be possibly illusory.

Female.—Somewhat larger and more robust, the scape normal; flagellum very faintly brownish beneath.

Abyssinia; two males and a female. Donated by R. E. Turner, but evidently not collected by him.

HYLAEUS SIMULANS, new species

Female.—Length nearly 7 mm.; black, with white markings as follows: narrow lateral bands along orbits, a small spot in middle of lower part of clypeus in holotype, but not in the others, continuous band on collar, and spot on tegulae; tubercles black, the margin ciliate; wings dusky, basal nervure falling a trifle short of nervulus, first recurrent meeting intercubitus. This is part of Turner's No. 7, which also includes *H. microstictus.* The two species do at first sight seem to be very much alike, but the present insect lacks the clypeal pit and has a narrower face. As in *H. microstictus,* the front tergite is very minutely punctured. The clypeal spot suggests *H. immarginatus* (Alfken), which differs at once by the black collar, and the distinctly shining mesonotum, with strong well-separated punctures.

Cape Province: Mossel Bay (type locality), six, March 1922, March-April 1932, April 1933 (R. E. Turner); Katberg, 4,000 feet, November 14-26, 1932 (Turner).

HYLAEUS SUBREDITUS, new species

Female.—Length about 6.7 mm.; black, robust, with a large transverse shining clypeal pit; no light markings anywhere, except short lateral marks next to orbits at level of antennae, and a small spot on tegulae; wings dusky. In almost all respects this agrees with *H. reditus* Cockerell; it has the first tergite excessively minutely and closely punctured, and a conspicuous line of white hairs sublaterally on margin of first and second tergites. It is larger and more robust than *H. reditus,* and the mesonotum and scutellum, seen from above, are entirely dull, whereas in *H. reditus* the sides of disk of scutellum, and corresponding areas on hind part of mesonotum are polished and shining. The sides of the metathorax are dull.

Cape Province: Somerset East, November 1930 (R. E. Turner, 12).

In addition to the type, there is another like it, and a third, smaller, specimen, with clearer wings. This last looks much more like *H. reditus,* but it is not that species, and for the present I regard it (as did Turner) as a variation of *H. subreditus.*

Turner has given the same number (12) to a male from Somerset East, November 1930, and I accept it as the male of *H. subreditus,* without any more proof than the general similarity, the identical date, and Turner's opinion. It is about 5.5 mm. long, with dusky, highly iridescent wings. In my table in American Museum Novitates, No. 847, p. 9, 1936, it runs to *H. abjunctus* Cockerell, having the face creamy white, and the hind tibiae black. The first abdominal sternite, seen in lateral view, shows a strong protuberance. From *H. abjunctus* it differs thus: inner corners of lateral face marks opposite middle of supraclypeal mark; flagellum very obscurely reddish beneath; mesothorax and scutellum hardly shining, the punctures not evident under a lens; basitarsi not white. The basal nervure nearly meets the intercubitus, and the first recurrent joins the first cubital cell near the end. The tegulae are entirely black, the scape is swollen, but not excessively so, and is very finely punctured at upper end. The microscope shows the mesonotum to be strongly, extremely densely, punctured, the punctures tending to run in transverse lines. If this is *H. subreditus,* it appears to belong with the smaller variety, which it superficially resembles very closely.

HYLAEUS XANTHOSTOMA (Alfken)

Female.—Length about 5 mm.; slender, black, with the clypeus and the region of the mouth red, not yellow as the name given by Alfken would imply. The type locality is Sunday River in South Africa. Turner took six females at Okahandja, December 1927 and March 1928. The same species has been reported from the Belgian Congo and Nigeria. The male is described from Stanleyville; no South African males have been seen. One female was taken by Turner at Umtata, Transkei, February-March 1923. This has an altitude of 2,300 feet.

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Some of the early descriptions of American fresh-water amphipods are so unintelligible and the figures so meager or incorrect that the true status of these species remains in doubt until subsequent authors redescribe and figure them in greater detail from specimens from the type localities. *Stygobromus vitreus,* described by Prof. E. D. Cope from Mammoth Cave, Ky., in 1872, was redescribed and figured by Prof. S. I. Smith in 1888 and placed in the genus *Crangonyx.* I am here describing and figuring this species in greater detail than did Professor Smith and am leaving it in its original genus, *Stygobromus.*

Prof. A. S. Packard in 1881 described *Crangonyx antennatus* from Nickajack Cave, Shellmound, Tenn., and it was later redescribed and figured by Dr. W. P. Hay, who placed it in the genus *Niphargus.* As this genus does not occur in America, I have examined specimens studied by Dr. Hay and find that they belong in the genus *Crangonyx.* I have, therefore, redescribed and figured the species in detail.

Ada L. Weckel in 1907 described a species, *Gammarus caecus,* from a cave in Cuba. The species has ever since remained a mystery and, as it could not, from the structure of the gnathopods, be a *Gammarus,* I have therefore examined her material and find that it is not a *Gammarus,* but represents a new genus, which I am designating *Weckelia.*

In 1931 some amphipods were taken from a slightly brackish pond on the island of Curaçao, which Dr. K. Stephensen [1] placed in a new genus, describing them as *Metaniphargus curasavicus.* The United States National Museum in 1937 received from Harry A. Beatty some amphipods taken on the island of St. Croix, which, upon study, were found to belong to Dr. Stephensen's genus and to represent a new species. I am describing this species as *Metaniphargus beattyi* in honor of its discoverer.

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[1] Stephensen, K., Zool. Jahrb. Syst., vol. 64, Nos. 3/5, p. 426, figs. 6-8, 1933.

At the present time there is much active interest in cave explorations, and the cave faunas are receiving their share of attention. As a result, many new and interesting animals are being discovered. Kenneth Dearolf, in 1937 and 1938, while exploring caves in Pennsylvania, collected some rather large amphipods which he sent to the National Museum for identification. These specimens represent a new species which I am describing and naming *Crangonyx dearolfi.*

In 1938 I described the species *Synpleonia pizzini* from the District of Columbia, but gave no figures. I am, therefore, giving a few further notes on this species and adding figures.

New species of American fresh-water Amphipoda are being frequently discovered, and undoubtedly new genera will come to light, so it is scarcely possible at the present time to form a key that will remain effective very long. However, it may prove useful to present in key form our present knowledge of the families and genera of such of these animals as are known to occur in America. I am therefore giving such a key.

The four families *Corophiidae, Talitridae, Haustoriidae,* and *Gammaridae* are represented in the fresh waters of America.

KEY TO THE FAMILIES OF AMERICAN FRESH-WATER AMPHIPODA

1. Body dorso-ventrally depressed; antenna 2 very strongly developed; gnathopod 2 simple; telson very short and entire .... **Corophiidae**
   Body laterally compressed; antenna 2 not strongly developed; gnathopod 2 subchelate; telson entire or cleft 2
2. Antenna 1 shorter than antenna 2 and without accessory flagellum; mandible without palp; maxilla 1 with small 1-jointed palp; uropod 3 with a single ramus; telson small and entire .... **Talitridae**
   Antenna 1 with accessory flagellum; mandible with palp; maxilla 1 with 2-jointed palp; uropod 3 with or without rami; telson entire or cleft.... 3
3. Antenna 1 shorter than antenna 2, flagellum in female very short, in fully developed male very long; peraeopod 5 much shorter than 4 with second joint greatly expanded; telson deeply cleft .... **Haustoriidae**
   Antenna 1 either longer or shorter than 2, but with both antennae rather long and slender; accessory flagellum very short, consisting of one or two short joints, or well developed and consisting of from three to seven joints; peraeopods more or less slender with second joint of peraeopods 3 to 5 only moderately expanded; peraeopod 5 longer or very little shorter than 4; telson entire or cleft .... **Gammaridae**

Family COROPHIIDAE

This family is represented by the genus *Corophium* and the species *C. spinicorne* Stimpson,[2] which, although described from San Fran-

[2] Stimpson, Wm., Boston Journ. Nat. Hist., vol. 6, p. 514, 1857.

cisco Bay, Calif., has been taken from the water supply of the city of San Francisco.

Family TALITRIDAE

The genus *Hyalella* is the only one of the family occurring in the fresh waters of America. The species *H. azteca* (Saussure),[3] described from Vera Cruz, Mexico, is widely distributed in North and South America, and occurs also in the form *inermis* Smith,[4] which lacks the dorsal teeth. Many species of this genus have been described from South America, but it is very probable that a number of them will prove to be synonyms of *H. azteca.* I have examined specimens of *H. ornata* described by Prof. A. S. Pearse[5] from Vera Cruz, Mexico, and find that it is a synonym of *H. azteca* (Saussure).

Family HAUSTORIIDAE

This family is represented by the genus *Pontoporeia* and by the species *P. affinis* Lindstrom,[6] which inhabits the cold lakes of the northern United States and Canada. Two species, *P. hoyi*[7] and *P. filicornis,*[8] were described by Prof. S. I. Smith, the former from Lake Superior and the latter from Lake Michigan. He at first believed *P. hoyi* to be identical with *P. affinis* of the Scandinavian lakes, but subsequently decided that it represented a new species. The studies of Sven G. Segerstrale[9] have proved conclusively that *P. hoyi* is identical with *P. affinis* and that *P. filicornis* is the final and mature sexual stage of the male of *P. affinis. P. kendalli,* described by Arthur H. Norton[10] in 1909 from a specimen taken in the river below the lock dam in Chamberlain Lake, Me., is also considered by Segerstrale to be a synonym of *P. affinis.* The form *P. filicornis,* described by Adamstone[11] in 1928 from Lake Ontario and Lake Nipigon, is re-

[3] Saussure, Henri de, Mem. Soc. Phys. et Hist. Nat., Genève, vol. 14_1, p. 474, pl. 5, fig. 33, 1858.

[4] Smith, S. I., Rep. U. S. Geol. Surv. Terr., 1873, p. 609, pl. 1, figs. 1, 2, 1874.

[5] Pearse, A. S., 13th Rep. Michigan Acad. Sci., p. 109, fig. 2, 1911.

[6] Lindstrom, G., Öfv. Akad. Förh., vol. 12, p. 63, 1855.

[7] Smith, S. I., Rep. U. S. Fish Comm., 1872-73, vol. 2, p. 647, pl. 2, fig. 5, 1874.

[8] Idem, p. 649.

[9] Segerstrale, Sven G., Studien über die Bodentierwelt in Sudfinnländischen Kustengewässern III. Zur Morphologie und Biologie des Amphipoden Pontoporeia affinis, nebst einer Revision der Pontoporeia-Systematik. Soc. Scientiarum Fennica. Comm. Biol., vol. 7, No. 1, Helsingfors, 1937.

[10] Norton, A. H., Proc. Portland Soc. Nat. Hist., vol. 2, p. 247, fig. 1, 1909.

[11] Adamstone, F. B., Trans. Amer. Micros. Soc., vol. 47, No. 3, p. 366, pl. 52, 1928.

garded by Segerstrale to be the mature male of a special form of *P. affinis,* and he suggests that it be designated form *brevicornis.*

Family GAMMARIDAE

Dr. A. Schellenberg has divided the related fresh-water genera of the Gammaridae into two sections, the *Gammarus* section and the *Crangonyx* section. As this family is represented in America by a number of fresh-water genera, I have followed his plan and grouped them under these sections, which may be characterized as follows.

KEY TO THE SECTIONS OF THE GAMMARIDAE

Antenna 1, accessory flagellum of 3 to 7 joints; gnathopods 1 and 2 subchelate, either very similar or dissimilar, palms when armed bearing only simple spine teeth; urosome segments free and bearing single or groups of dorsal spines; without sternal gills; uropod 3 well developed, inner ramus sometimes greatly reduced; telson cleft to base or nearly so. . **Gammarus** section

Antenna 1, accessory flagellum very small, rudimentary or consisting of one long and one short joint; gnathopods 1 and 2 subchelate, usually very similar and much alike in male and female, palms armed throughout with numerous notched spine teeth (except in gnathopod 1 of *Metaniphargus*); urosome segments free or coalesced and without groups of dorsal spines; uropod 3 usually reduced and inner ramus, when present, short or scalelike; sternal gills present or absent; telson entire, or slightly or deeply incised **Crangonyx** section

KEY TO THE GENERA OF THE GAMMARUS SECTION

1. Coxal gills with cylindrical appendages; gnathopod 1 of male larger than gnathopod 2, palm slightly oblique and armed throughout with many blunt, peglike teeth; uropod 3 with inner ramus very small **Anisogammarus**[12]

   Coxal gills without cylindrical appendages; gnathopod 1 of male smaller than gnathopod 2 2
2. Gnathopod 1 of male, palm long, very oblique, and armed with only one or two spine teeth in addition to those at palmar angle........ **Gammarus**[13]

   Gnathopod 1 of male, palm short, slightly oblique and without true spine teeth .... **Weckelia**

The genus *Anisogammarus* is confined to the Pacific coasts of Asia and North America, the only American fresh-water species so far described being *A. ramellus* (Weckel),[14] recorded from California and Oregon.

[12] Derjavin, A. N., The Gammaridae of the Kamchatka Expedition, 1908-1909. Russ. Hydrobiol. Zeitschr., vol. 6, Nos. 1-2, p. 8, 1927.

[13] Fabricius, J. C., Syst. Ent., p. 418, 1775.

[14] Weckel, Ada L., Proc. U. S. Nat. Mus., vol. 32, No. 1507, p. 38, 1907.

The genus *Gammarus* is widely distributed over North America and is represented by a number of species, but it does not occur in the West Indies or in South America.

The genus *Weckelia* has been found only in Cuba and it is represented by the single species *Weckelia caeca* (Weckel).

KEY TO THE GENERA OF THE CRANGONYX SECTION

1. Urosome segments coalesced.......................................2
   Urosome segments not coalesced.......................................4
2. Sixth and seventh mesosome segments bearing bifurcate lateral sternal gills **Synpleonia**[15]
   Sixth and seventh mesosome segments bearing simple lateral sternal gills..3
3. Telson entire ....**Stygonectes**[16]
   Telson cleft ....**Synurella**[17]
4. Uropod 3, peduncle without rami.......................**Apocrangonyx**[18]
   Uropod 3, peduncle with rami.......................................5
5. Uropod 3, peduncle with one 1-jointed ramus................**Stygobromus**
   Uropod 3, peduncle with two rami, inner ramus short or scalelike........6
6. Uropod 3, outer ramus 2- or several-jointed..........................7
   Uropod 3, outer ramus 1-jointed.......................................8
7. Coxal gill of gnathopod 2 with cylindrical appendage; palm of gnathopod 1 oblique and not short; inner ramus of uropod 3 very short..**Allocrangonyx**[19]
   Coxal gill of gnathopod 2 without cylindrical appendage; palm of gnathopod 1 slightly oblique and very short; inner ramus of uropod 3 nearly half the length of first joint of outer ramus..................**Metaniphargus**[20]
8. Lateral sternal gills of sixth mesosome segment bifurcate; accessory flagellum of antenna 1 rudimentary.........................**Falklandella**[21]
   Lateral sternal gills of sixth mesosome segment simple; accessory flagellum of antenna 1 2-jointed.......................................9
9. Uropod 3, outer ramus longer than peduncle; first four coxal plates deeper than their segments; lower posterior corners of the second and third metasome segments right-angled or sharply produced........**Crangonyx**[22]
   Uropod 3, outer ramus as long as, or shorter than, peduncle; first four coxal plates shallower than their segments; lower posterior corners of second and third metasome segments broadly rounding............**Bactrurus**[23]

With the exception of the genus *Falklandella,* which was described by Dr. A. Schellenberg from the Falkland Islands off the southeast

[15] Creaser, E. P., Occ. Pap. Mus. Zool., Univ. Michigan, p. 1, 1934.
[16] Hay, W. P., Proc. U. S. Nat. Mus., vol. 25, No. 1292, p. 430, 1902.
[17] Wrzesniowski, A., *in* Hoyer, Zeitschr. Wiss. Zool., Leipzig, vol. 28, p. 403, 1877.
[18] Stebbing, T. R. R., Trans. Linn. Soc. London, ser. 2, vol. 7, p. 422, 1899.
[19] Schellenberg, A., Mitt. Zool. Mus., Berlin, vol. 22, No. 1, p. 33, 1936.
[20] Stephensen, K., Zool. Jahrb., vol. 64, Nos. 3/5, p. 426, 1933.
[21] Schellenberg, A., Zool. Anz., vol. 91, Nos. 1/4, p. 82, figs. 1 and 7, 1930.
[22] Bate, Spence, Proc. Dublin Univ. Zool. Bot. Assoc., vol. 1, p. 237, 1859.
[23] Hay, W. P., Proc. U. S. Nat. Mus., vol. 25, No. 1292, p. 430, 1902.

coast of South America, and the genus *Metaniphargus* described by Dr. K. Stephensen from the island of Curaçao and now recorded from the island of St. Croix, all the genera of the *Crangonyx* section are confined to North America, but the genus *Crangonyx* occurs also in Europe, and the genus *Synurella* occurs also in Europe and Asia.

STYGOBROMUS Cope, 1872

The genus *Stygobromus* was described by E. D. Cope in 1872 from specimens taken in Mammoth Cave, Ky., but his descriptions of the genus and the genotype, *S. vitreus,* were so unintelligible that subsequent students were not able to recognize the animal until S. I. Smith, in 1888, redescribed the species from specimens procured from the type locality, placing it, however, in the genus *Crangonyx*. Smith believed that *Stygobromus* was a synonym of *Crangonyx,* as Bate had erroneously described the third uropods of *Crangonyx* as uniramous.

In 1873 A. S. Packard [24] examined specimens from three wells in Orleans, Ind., and identified them as *Crangonyx vitreus*. S. I. Smith in 1875 examined Packard's specimens from the wells in Orleans and found them to be very different from Mammoth Cave specimens, stating that they were closely allied to *Crangonyx gracilis* from Lake Superior.

Dr. W. P. Hay, in 1897, in speaking of the Crustacea of the caves of Indiana, said that *Crangonyx vitreus* was represented in the collection by nearly a dozen small specimens which were taken from a wooden trough in Salt Petre Cave, Crawford County. In 1902 [25] Hay said, "This species [*Crangonyx vitreus*] was observed in considerable numbers in Mammoth Cave, both in its type locality, Richardson's Spring, and in the Roaring River district in small pools."

Ada L. Weckel in 1907 gave a short description and figures of *Crangonyx vitreus,* which were made from specimens that were sent to her from the United States National Museum under the name *Crangonyx vitreus* Packard. In 1905 Prof. S. J. Holmes figured *Crangonyx vitreus* from specimens which were sent to him from the United States National Museum, but the specimens were evidently incorrectly identified, as his figures do not represent that species.

In 1913 Prof. A. S. Pearse recorded *Crangonyx vitreus* from a creek 80 miles north of Rampart House, Alaska. As this locality was

[24] Packard, A. S., 5th Ann. Rep. Peabody Acad. Sci., p. 95, 1873.

[25] Hay, W. P., Proc. U. S. Nat. Mus., vol. 25, No. 1285, p. 225, 1902.

so much farther north than any previous record and as the specimens were from a creek, I wished to examine them, but they could not be located at the museum of the University of Michigan. In 1917 Professor Pearse reported the species from a well at Randolph, Wis.

Dr. A. Schellenberg in 1936 recognized *Stygobromus,* giving a short characterization of the genus, and including in it the species *S. vitreus* Cope, *S. bifurcus* (Hay) and *S. putealis* (Holmes).

I have examined specimens of *Stygobromus* from Richardson's Spring, Mammoth Cave, Ky., and the characters of the genus may be given as follows: Blind. Antenna 1 longer than antenna 2. Accessory flagellum of antenna 1 2-jointed. Gnathopods 1 and 2 subchelate, 2 stronger than 1. Coxal plate 4 somewhat excavate behind. Second joints of peraeopods 3 to 5 moderately expanded. Mandible, molar well developed; cutting edge toothed; accessory plate well developed; three spines in spine row; palp short and stout, second and third joints subequal in length. Maxilla 1, inner plate bearing a few plumose setae; outer plate armed with seven serrate spine teeth; palp 2-jointed and bearing apical spines and setae. Maxilla 2, inner plate wider than outer and bearing an oblique row of plumose setae. Maxillipeds with inner and outer plates well developed; inner plate as long as, or longer than, outer and bearing two serrate spine teeth; outer plate without marginal teeth; palp 4-jointed, short and stout. Lower lip with mere suggestion of inner lobes; lateral lobes large and bluntly rounding. Simple stalked coxal gills and simple sternal gills present. Uropod 3 uniramous, ramus 1-jointed and shorter than peduncle. Telson short, about as long as wide, and distally slightly excavate or entire.

STYGOBROMUS VITREUS Cope

Figures 1, 2

Stygobromus vitreus Cope, 1872, Amer. Nat., vol. 6, p. 422.
Crangonyx vitreus Smith, 1874, Rep. U. S. Fish Comm., 1872-73 [1874], p. 656.
Crangonyx vitreus Smith, 1875, Amer. Journ. Sci. and Arts, ser. 3, vol. 9, p. 476.
Crangonyx vitreus Smith, 1888, Mem. Nat. Acad. Sci., vol. 4, pt. 1, p. 34, pl. 5, figs. 1-4.
Crangonyx vitreus Hay, 1897, Indiana Dep. Geol. and Nat. Res., 21st Ann. Rep., p. 206.
Crangonyx vitreus Hay, 1902, Proc. U. S. Nat. Mus., vol. 25, No. 1285, p. 225.
Crangonyx vitreus Hay, 1902, Proc. U. S. Nat. Mus., vol. 25, No. 1292, p. 429.
Crangonyx vitreus Weckel, 1907, Proc. U. S. Nat. Mus., vol. 32, No. 1507, p. 49, fig. 13.
Crangonyx vitreus Banta, 1907, The Fauna of Mayfields Cave, Ind., p. 80.
Crangonyx vitreus Pearse, 1913, Occ. Pap. Mus. Zool., Univ. Michigan, No. 1, p. 3.

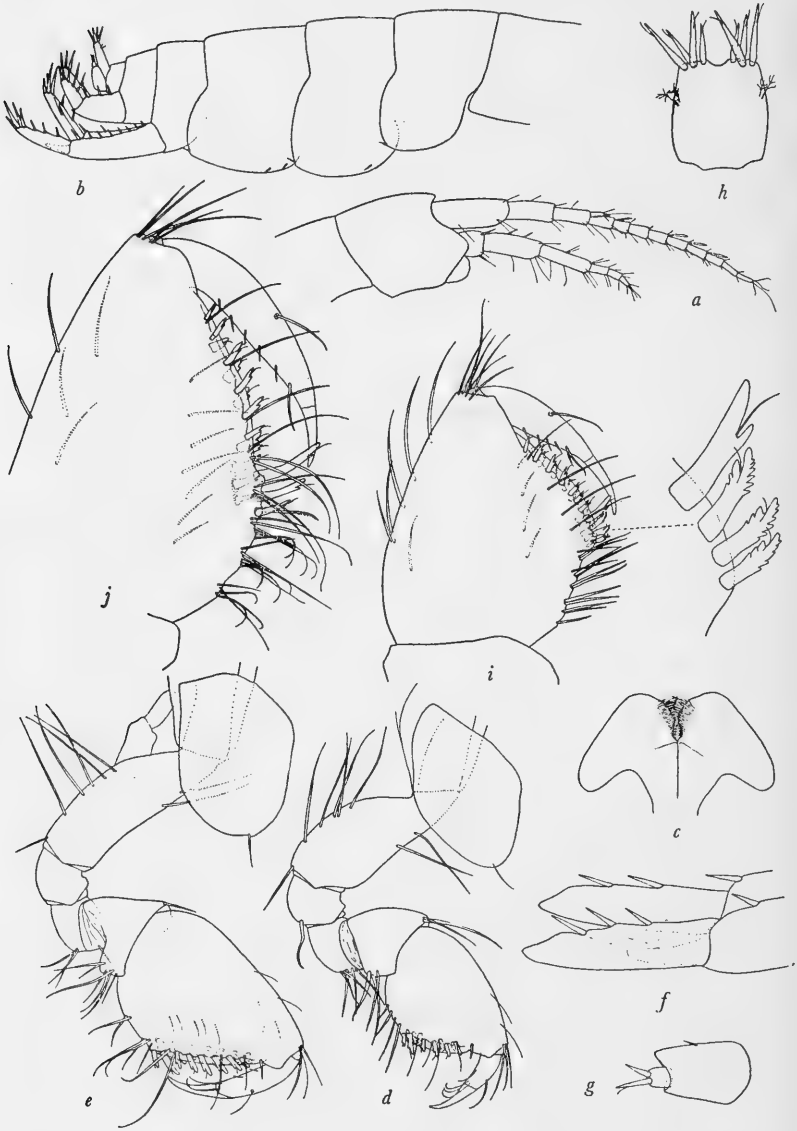

FIG. 1.—*Stygobromus vitreus* Cope. Male from Richardson's Spring, Mammoth Cave, Ky.: *a,* head and antennae; *b,* hind end of animal; *c,* lower lip; *d,* gnathopod 1; *e,* gnathopod 2; *f,* uropod 1; *g,* uropod 3; *h,* telson. Female from Buzzards Cave, Crystal Cave, Mammoth Cave, Ky.: *i,* gnathopod 1; *j,* gnathopod 2.

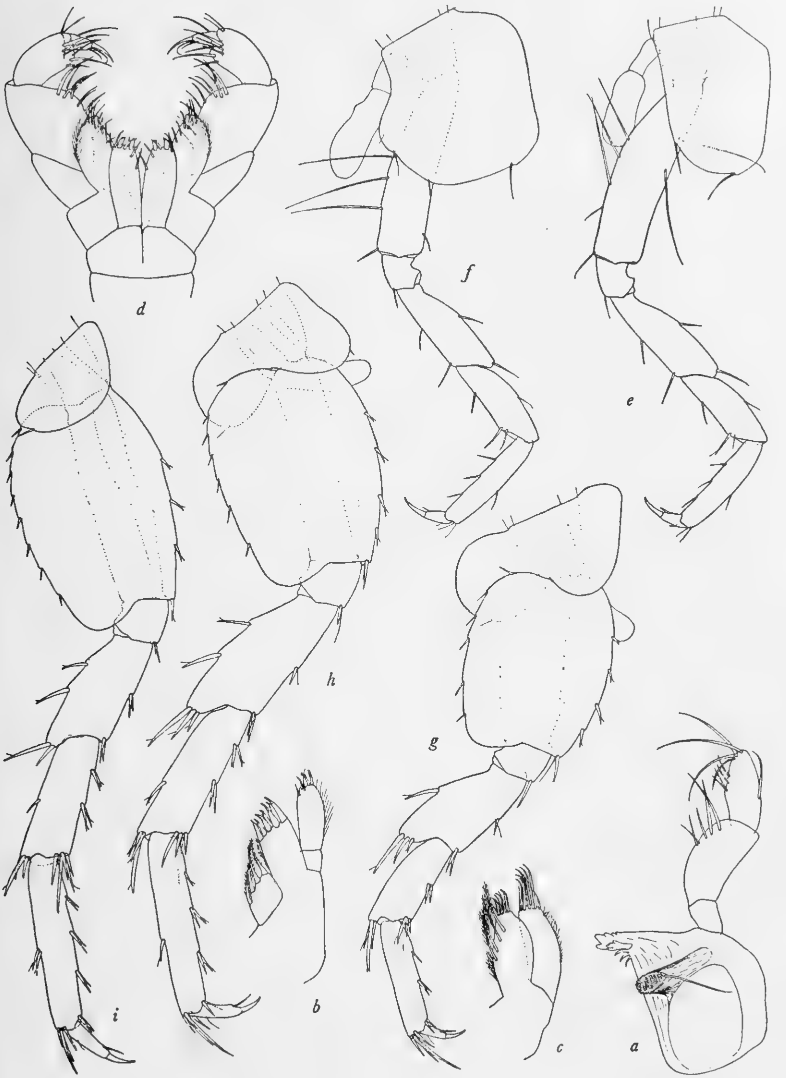

FIG. 2.—*Stygobromus vitreus* Cope. Male from Richardson's Spring: *a*, mandible; *b*, maxilla 1; *c*, maxilla 2; *d*, maxillipeds; *e*, peraeopod 1; *f*, peraeopod 2; *g*, peraeopod 3; *h*, peraeopod 4; *i*, peraeopod 5.

Crangonyx vitreus PEARSE, 1917, Occ. Pap. Mus. Zool., Univ. Michigan, No. 46, p. 8.

Stygobromus vitreus SCHELLENBERG, 1936, Mitt. Zool. Mus., vol. 22, No. 1, p. 37.

Male.—Head rather long; side lobe angularly produced and with narrowly rounding apex; without eyes. Antenna 1, peduncular joints successively shorter; flagellum very little longer than peduncle and composed of about nine joints, some of which carry slender sensory clubs; accessory flagellum shorter than first joint of primary flagellum and composed of two joints. Antenna 2 about half the length of antenna 1; fifth peduncular joint very little shorter than fourth; flagellum about as long as fifth peduncular joint and composed of about four joints.

Right mandible short, with about five teeth on cutting edge; accessory plate with 3-pronged cutting edge; three spines in spine row; molar rather prominent and bearing seta at inner corner; palp short and stout, second joint very little longer than third. Maxilla 1, inner plate with four plumose setae on the obliquely truncate distal margin; outer plate with seven serrate spine teeth; palp with four slender spines and one seta on distal edge, and fine setules on outer margin. Maxilla 2, inner plate wider, but slightly shorter than outer and bearing an oblique row of four plumose setae near inner margin; outer plate with the usual distal spines, and with fine setules on outer margin. Maxillipeds short and stout, inner plate narrower but a little longer than outer, armed distally with two serrate teeth and a few short spines; outer plate with inner distal angle slightly produced, inner margin without teeth but bearing a submarginal row of about seven spines; palp short and stout and bearing rather few spines, outer margin of third joint equal in length to outer margin of second, fourth joint bearing a long slender nail at the base of which are two spinules. Lower lip without inner lobes, side lobes large and broadly rounding distally.

Gnathopod 1 shorter than, and not as stout as, gnathopod 2, second joint a little longer than the sixth; fifth joint about half the length of sixth; sixth joint about a third longer than wide with front and hind margins slightly convex, palm oblique, slightly convex, about as long as hind margin of joint, defined by an evenly rounding curve, and armed on outside and inside margins with a few notched spine teeth; seventh joint fitting palm and bearing a long nail and several setae. Gnathopod 2, second joint about as long as sixth joint; fifth joint less than half the length of sixth; sixth joint, palm oblique, slightly convex, slightly longer than hind margin of joint, defined by a blunt angle, and armed on outside and inside margins with eight notched spine teeth; seventh joint fitting palm and bearing a long nail and several setae.

Peraeopods 1 and 2 equal in length and bearing very few spines, which are placed singly and not in groups; nail of seventh joint very long. Peraeopod 3 about as long as 2; second joint almost as wide as long, lower hind lobe dipping very slightly; remaining joints rather short and stout; seventh joint short with prominent nail. Peraeopods 4 and 5 about equal in length and longer than 3; second joint considerably expanded with lower hind lobe dipping very little; seventh joint proportionately longer than in peraeopod 3.

Uropod 1 extending farther back than 2, peduncle produced distally below into a long narrow process, rami subequal in length and much shorter than peduncle. Uropod 2, peduncle armed above with three spines, outer ramus shorter than inner which is very little shorter than peduncle. Uropod 3 scarcely reaching end of telson, ramus about one-quarter as long as peduncle and armed distally with two spines. Telson nearly as wide as long, distal margin with a very shallow central excavation; each lobe armed with four spines, and either lateral margin bearing two plumose setules. Length, about 4 mm. Mesosome segments 2, 3, and 4 each bearing a single, cylindrical, median sternal gill. Mesosome segments 6 and 7 each bearing a pair of lateral sternal gills. Mesosome segment 7 is without coxal gills. The gill arrangement of the two sexes is alike.

Female.—Palm of gnathopod 1 bears at the rounding defining angle a long stout spine beyond which are three shorter spines which are both notched and serrate. Palm of gnathopod 2 bears at the defining angle a long stout spine, beyond which are two shorter spines which are notched only.

WECKELIA, new genus

In 1907 Ada L. Weckel described the species *Gammarus caecus* from Modesta Cave, near Cañas, Cuba. Her description is very incomplete and she figures only the antennae and gnathopods. As Dr. A. Schellenberg has already remarked, the species could not possibly belong to the genus *Gammarus* from the character of the first gnathopods alone. I have examined the original fragmentary specimens and have formed a new genus for the reception of the species, which I here designate as *Weckelia* in honor of Miss Weckel, who most usefully, in 1907, brought together in one publication all the genera and species of fresh-water amphipods known at that time in North America.

The genus *Weckelia* may be characterized as follows: Without eyes. First antenna longer than second, with flagellum much longer than peduncle. Accessory flagellum of several joints. Second antenna with flagellum shorter than peduncle; gland cone prominent. Mandible with molar well developed; accessory plate present; several spines in spine row; palp reduced to one small joint. First maxilla, inner plate broad, bearing 12 or 13 plumose setae; outer plate bearing 9 spine teeth; palp 2-jointed. Second maxilla, inner plate a little wider than outer and bearing an oblique row of plumose setae. Maxilliped, inner plate armed distally with three spine teeth; outer plate bearing a row of spine teeth on inner margin; palp 4-jointed. Lower lips with inner lobes very small and indistinct; lateral lobes prominent. First gnathopod, in female, with fifth joint longer and wider than sixth; sixth joint narrow, with palm short and slightly oblique. Second gnathopod in female larger than first; fifth joint shorter, but wider than sixth; sixth joint narrowing distally and with palm very oblique. Coxal plates 1 to 4 much deeper than their segments, fourth excavate behind. Pleopods well developed. Urosome segments free, second segment bearing a single dorsolateral spinule on either side. Third uropods missing. Telson cleft to base, with lobes widely dehiscent. Gills simple. No sternal gills discernible.

Genotype.—Gammarus caecus Weckel.

WECKELIA CAECA (Weckel)

FIGURES 3, 4

Gammarus caecus WECKEL, 1907, Proc. U. S. Nat. Mus., vol. 32, p. 47, fig. 12.

Female.—Head, lateral lobes rather small with evenly rounding lower corner. Antenna 1, second joint longer than first; third joint over one-third the length of second, flagellum composed (according to Weckel) of 20 to 30 joints; accessory flagellum 4-jointed, the last joint very small. Antenna 2 (according to Weckel) about two-thirds the length of antenna 1; fifth joint a little shorter than fourth; flagellum of about 13 joints. Mandible, molar well developed with a plumose seta on right but not on left molar; cutting edge toothed; accessory plate simple with toothed cutting edge; five spines in spine row; palp very small and consisting of only a single joint bearing apically two setae. Maxilla 1, inner plate very well developed, with the oblique edge bearing 12 or 13 plumose setae and a row of simple spinules; outer plate armed with 9 spine teeth; palp, second joint bearing distally an oblique row of about 8 short spines submarginal to which is an oblique row of 5 slender spinules. Maxilla 2, inner plate with diagonal row of closely set plumose setae which curves inward considerably at the distal end. Maxillipeds, inner plate about as long as outer plate, bearing three spine teeth on distal margin and (in the specimen figured) two smaller teeth on the upper inner margin; outer plate armed with about five to seven spine teeth on inner margin; palp, fourth joint curved, bearing fine setules on inner edge and a short nail apically.

Gnathopod 1, coxal plate with side margins nearly parallel, lower corners evenly rounding and hind corner bearing two short spines; fifth joint longer and wider than sixth, expanded distally with the lower margin bearing a group of spines and a brush of very fine setules; sixth joint about twice as long as wide, slightly expanded distally, and bearing a few groups of spines; palm slightly oblique, convex, bearing a row of four submarginal spines on outside and five on inside; seventh joint curved and fitting palm. Gnathopod 2, coxal plate slightly expanded distally, lower margin evenly convex with the rounding hind corner bearing two or three short spines; fifth joint more expanded proportionately than that of gnathopod 1, but similarly armed; sixth joint widest proximally, palm very oblique with a slight concavity toward the long defining spine, bearing five or six submarginal spines on the outside, and merging imperceptibly into the convex hind margin of joint; hind margin bearing two groups of spines; seventh joint strong, slightly curved, and as long as palm.

Peraeopods 1 and 2 slender and much alike, seventh joint slightly curved and bearing a seta at the base of the nail. Peraeopods 3 to 5 much alike, second joint considerably expanded, front margin bearing short spines and the hind margin serrate with a seta at each serration; lower portion of all peraeopods missing. Coxal plate 3, lower margin convex and bearing two short spines at the rounding hind corner. Coxal plate 4, lower margin convex and bearing a few setules but no spines. Coxal plate 5 with hind lobe the deeper.

Metasome segment 1 with lower margin produced into two small teeth; segments 2 and 3 with lower hind angle scarcely at all produced, lower margins bearing one or two spinules, and hind margin bearing a single setule just above the lower angle. Pleopods all well developed. Urosome segment 2, hind margin with a subdorsal spine on either side. Uropod 1 bearing a prominent spine on lower margin of peduncle near the base; rami imperfect. Uropod 2, outer ramus equal in length to peduncle, inner ramus longer than outer. Weckel says that in uropods 1 and 2 the rami are about equal in length, but this apparently is not correct. Uropod 3 missing. Telson is about twice as wide as long, cleft to base with lobes very widely separated,

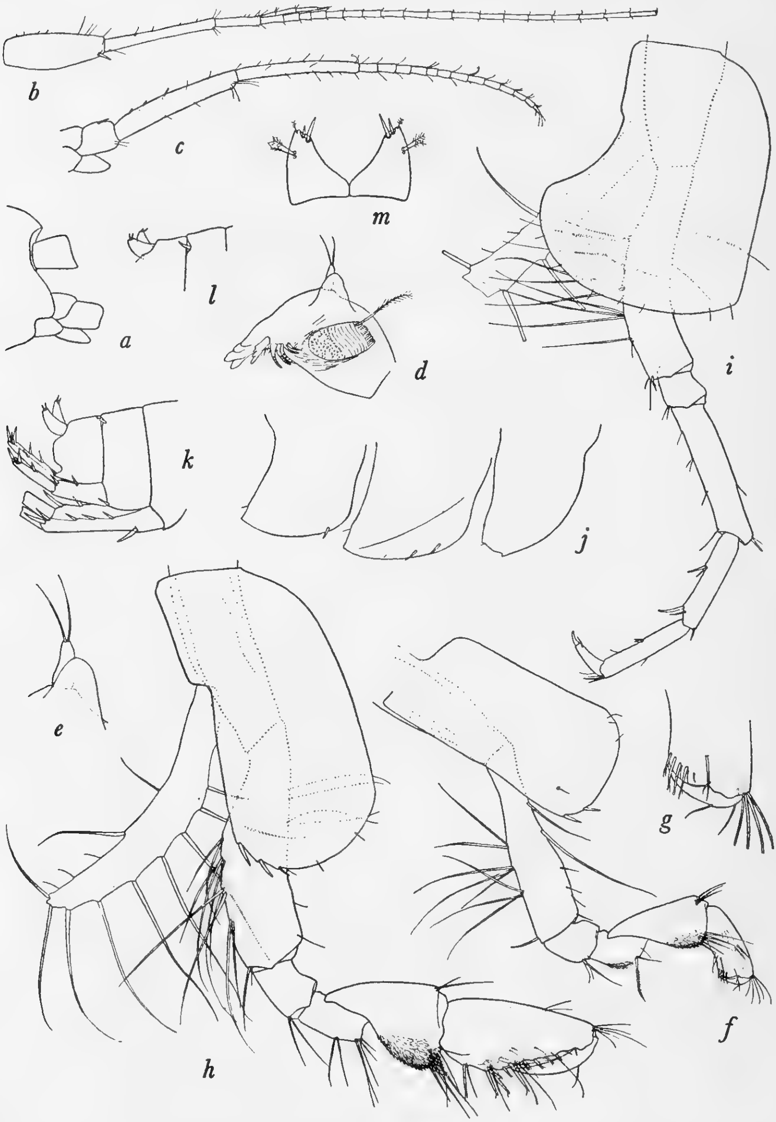

FIG. 3.—*Weckelia caeca* (Weckel). Female: *a,* front of head; *b,* antenna 1; *c,* antenna 2; *d,* mandible; *e,* mandibular palp; *f,* gnathopod 1; *g,* end of sixth joint of gnathopod 1 greatly enlarged; *h,* gnathopod 2; *i,* peraeopod 2; *j,* metasome segments; *k,* urosome and uropods 1 and 2; *l,* urosome segments 2 and 3 showing one of the dorsolateral spines; *m,* telson.

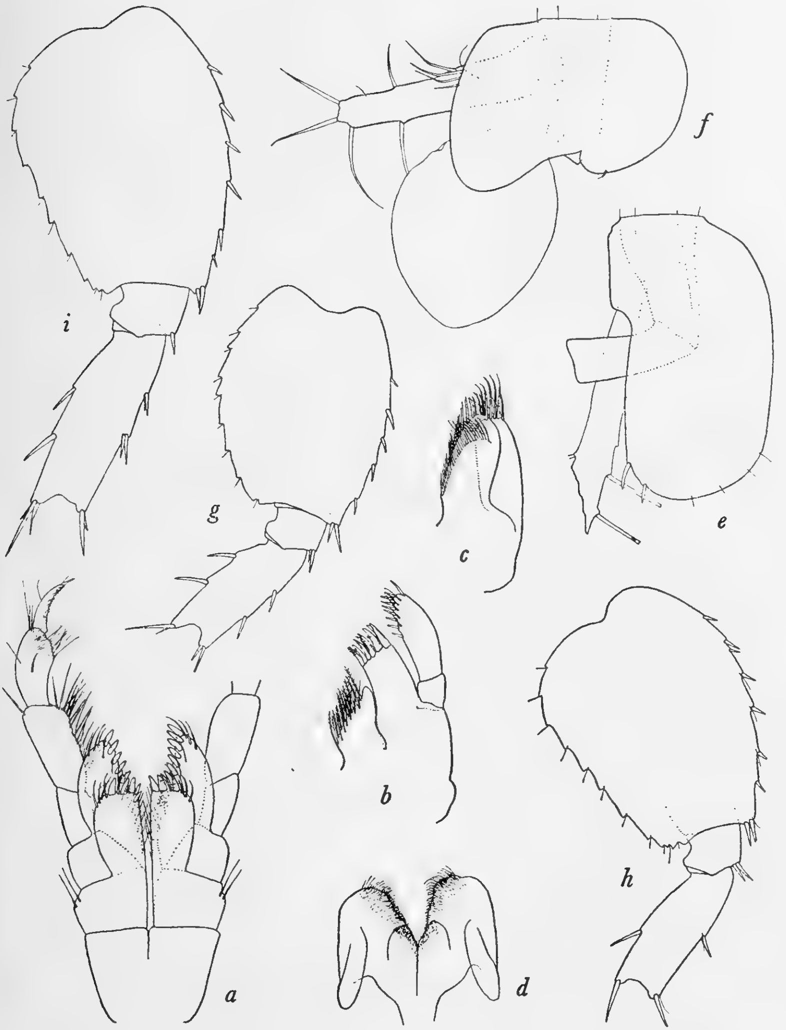

FIG. 4.—*Weckelia caeca* (Weckel). Female: *a*, maxillipeds; *b*, maxilla 1; *c*, maxilla 2; *d*, lower lip; *e*, coxal plate 3; *f*, coxal plate 5; *g*, peraeopod 3; *h*, peraeopod 4; *i*, peraeopod 5.

each lobe armed apically with two short spines and a plumose setule, and the lateral margins each bearing two plumose setules near the distal end. Length of female about 10 mm.

Remarks.—The specimen that I have figured and described is a female. Miss Weckel's figures and description are said to be of a male, and if this is correct the sexes are apparently alike.

CRANGONYX ANTENNATUS Packard

FIGURES 5, 6

Crangonyx antennatus PACKARD 1881, Amer. Nat., vol. 15, p. 880, fig. 2; 1888, Mem. Nat. Acad., vol. 4, p. 36, figs.

Eucrangonyx antennatus STEBBING 1899, Trans. Linn. Soc. London, ser. 2, vol. 7, p. 423.

Niphargus antennatus W. P. HAY, 1902, Proc. U. S. Nat. Mus., vol. 25, p. 430, figs. 6 and 11; Weckel 1907, Proc. U. S. Nat. Mus., vol. 32, p. 36, fig. 6.

Professor Packard described this species from Nickajack Cave, Tenn., but, as was so often the case with early descriptions and figures, his description was not accurate enough for the recognition of the species. Dr. W. P. Hay in 1902 redescribed and figured the species from specimens which he took at various places in Nickajack Cave, and, believing that the outer ramus of the third uropods possessed a small second joint, placed the species in the genus *Niphargus*. Ada L. Weckel in 1907 redescribed and figured the species, but added nothing of importance. She followed Hay in figuring and describing the outer ramus of the third uropod as consisting of two joints, and retained the species in the genus *Niphargus*.

Recently I examined specimens of this species which were taken by Dr. Hay in Nickajack Cave and find that it is a *Crangonyx,* as it agrees with this genus in all characters. The outer ramus of the third uropod is considerably constricted at the last group of lateral spines which gives somewhat the appearance of forming a short second joint.

Packard gives the length of the species as 6 to 7 mm. Hay does not give the length of his specimens. Weckel, who presumably used specimens collected by Hay for study, gives the length as 10 mm. The largest specimens which I measured were about 8.5 mm.

Female.—Head rather long with prominent side lobes which have evenly rounding corners. No eyes were discernible in the specimens examined, but Packard and Hay figure very small, slightly pigmented eyes. Antenna 1 long; first joint of peduncle slightly shorter than the second, which is twice the length of the third. Antenna 2 short;

fourth joint slightly longer than fifth; flagellum about the length of the fifth peduncular joint and composed of eight joints.

Mandible with molar rather prominent; accessory plate with double serrate edge; eight spines in spine rows; palp with second and third joints about equal in length. Maxilla 1, inner plate with seven plumose setae; outer plate with seven serrate spine teeth; palp armed distally with six spines and several setae. Maxilla 2, inner plate wider than, but equal in length to, outer plate and bearing an oblique row of eight submarginal plumose setae. Maxilliped, inner plate a little longer than outer and armed distally with two teeth and a few setae; outer plate reaching to about the first third of the second joint of palp, bearing only short slender spines on inner margin and a few longer spines distally; palp rather short and stout; fourth joint slender and bearing a prominent nail. Lower lip with slight indications of inner lobes; side lobes very prominent. Coxal plates 2 to 4 are perhaps slightly deeper than their segments and broadly rounding below. Coxal plate 4 deeper than long. Packard speaks of the fourth plate being large and square, but it is no larger than is normal for the genus.

Gnathopod 1, second joint very little longer than the sixth; fifth joint a little over half the length of the sixth and bearing five groups of spines on the broadly rounding lower margin; sixth joint with palm oblique, slightly convex, defined by a stout spine beyond which is a short spine, and slightly longer than hind margin of joint; seventh joint fitting palm and bearing a few setae on inner edge. Gnathopod 2, second joint equal in length to sixth; fifth joint a little over half the length of the sixth and bearing on the broadly rounding lower margin five groups of spines; sixth joint twice as long as wide, palm very oblique, slightly convex, longer than the hind margin of joint and defined by a stout spine; seventh joint fitting palm and bearing a few short setae on the inner edge.

Peraeopods 1 and 2 subequal in length and much alike; seventh joint bearing a prominent nail at the base of which are two setae. Peraeopods 3 to 5 much alike in size and shape; second joint moderately expanded, oval, with lower hind margin forming a shallow lobe.

Metasome segments 1 to 3 with lower hind corner very slightly produced and lower margins bearing a few spinules. Uropod 1 extending back a little farther than 2, and uropod 2 a little farther than 3. Uropod 3, peduncle two-thirds the length of outer ramus; inner ramus bearing a single spine. Telson reaching to about the end of peduncle of uropod 3, cleft for about half its length with lobes widely separated and each lobe bearing three apical spines.

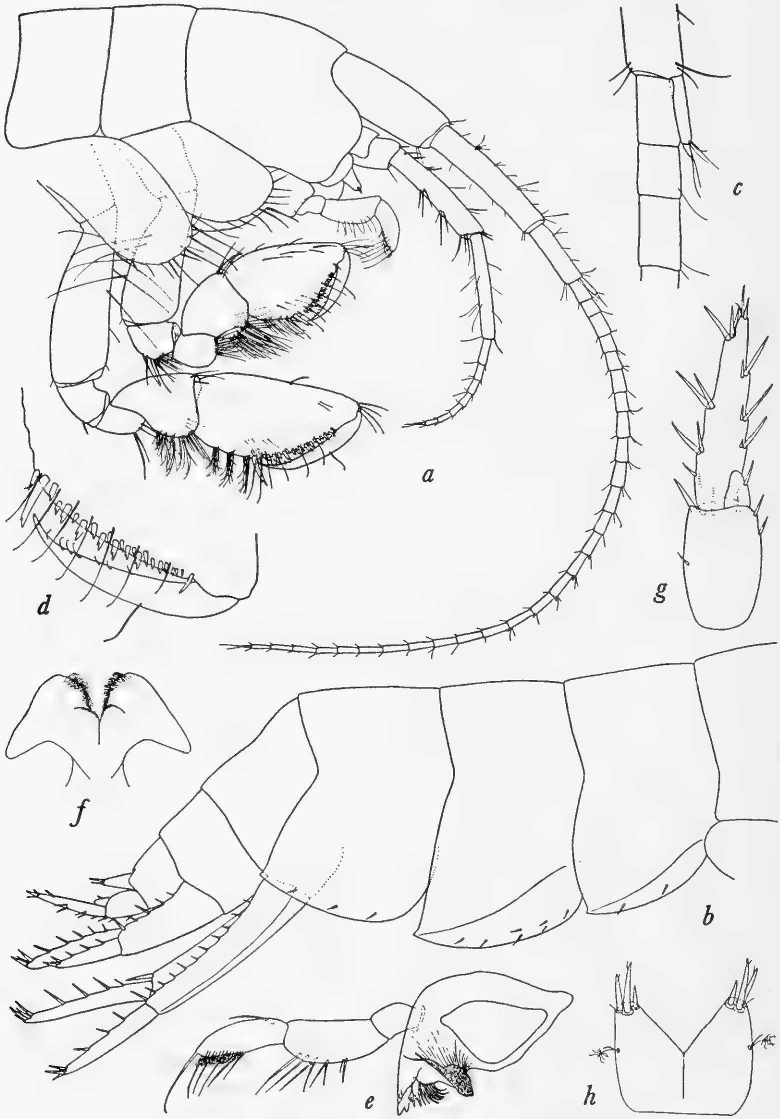

FIG. 5.—*Crangonyx antennatus* Packard. Female: *a*, anterior end of animal; *b*, posterior end of animal; *c*, accessory flagellum greatly enlarged; *d*, palm of gnathopod 1 greatly enlarged; *e*, mandible; *f*, lower lip; *g*, uropod 3; *h*, telson.

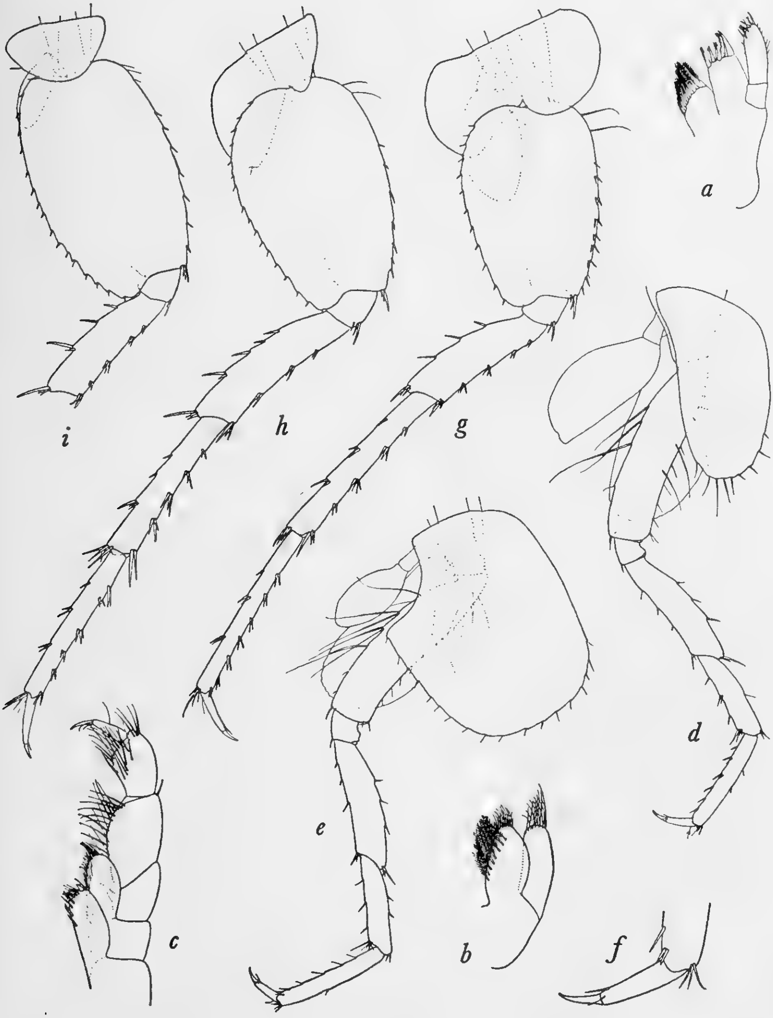

FIG. 6.—*Crangonyx antennatus* Packard. Female: *a*, maxilla 1; *b*, maxilla 2; *c*, maxilliped; *d*, peraeopod 1; *e*, peraeopod 2; *f*, seventh joint of peraeopod 2 greatly enlarged; *g*, peraeopod 3; *h*, peraeopod 4; *i*, peraeopod 5.

Mesosome segments 1 and 2 each bearing a simple, cylindrical, median sternal gill and mesosome segments 6 and 7 and metasome segment 1 each bearing a pair of simple lateral sternal gills. Length of female, from front of head to end of uropod 1, 8.5 mm.

CRANGONYX DEAROLFI, new species

Figures 7, 8

Male.—Head with side lobes prominent and rounding. Eye small, indistinct, consisting of only a few elements, and with very little color. Antenna 1 about one-half the length of the body; first and second joints about equal in length, third joint half the length of the second; flagellum much longer than peduncle, and consisting of from 25 to 33 joints, accessory flagellum consisting of 1 long and 1 very short joint. Antenna 2 much shorter than 1, fifth joint a little shorter than the fourth; flagellum short and consisting of from 9 to 12 joints; fourth and fifth joints of peduncle and the joints of the flagellum, except the distal few, bear club-shaped sense organs.

Maxillipeds with inner lobes longer and broader than outer; inner lobes armed distally with four stout spine teeth and three or four setae, two smaller spines at inner distal corner, and three spines on the oblique inner margin; outer lobe with narrowly rounding apex, inner margin armed with five or six spine teeth and marginal setae; palp stout, third joint bearing a short distal lobe, fourth joint bearing a minute nail and a few marginal setules. Maxilla 1 with inner lobe rounding and bearing three or four plumose setae; outer lobe armed with seven spine teeth which are distally serrate; palp armed distally with seven slender spines and a few setae. Maxilla 2, inner lobe broader than outer, and bearing an oblique row of three submarginal plumose setae. Right mandible with 3 or 4 teeth on the cutting edge; accessory plate strongly toothed; 9 or 10 spines in spine row; molar long and concave and bearing fine teeth only on the lower margin; palp with third joint little shorter than second. Lower lip with inner lobes small and rather poorly defined, both inner and outer lobes bearing fine setae but no spine teeth.

Gnathopod 1, palm quite oblique, convex, armed with about 12 notched spine teeth between which are scattered smaller teeth, and defined by a very slight rounding angle. The curve of the defining angle is armed with a row of six short closely set curved marginal spines, and opposite these is a similar row of submarginal bifurcate spines on the inside surface. Some of the smaller marginal spines nearer the hinge of the seventh segment are rather complex, bearing distally three or four sharp teeth and a seta. The hind margin of the sixth joint bearing several rows of setae, and the front margin several groups of setae. The seventh joint is of the same length and curvature as palm; inside margin bearing very fine setules, and the outer margin bearing longer ones. Gnathopod 2 much stouter than 1, with the very oblique, slightly convex palm nearly twice the length of the hind margin of the joint. Palm armed with about 12 notched spines between which are scattered smaller notched spines; the low, rounding defining angle bearing a long notched spine; 3 stout submarginal spines on inside surface of joint opposite the defining angle. Rear margin of joint bearing several groups of setae and the front margin with a few scattered setae. Seventh joint the length and curvature of palm, armed on inner margin with fine setules and on the outer margin with several longer ones.

Peraeopods 1 and 2 about equal in length and much alike in shape and armature; seventh joint bearing small nail and four setae on inner margin. Peraeopod 4 longer than 3 or 5 which are subequal in length. Hind margin of the second joint of peraeopods 3 and 5 is evenly convex, but that of 4 is nearly straight for the lower two-thirds. The seventh joint of peraeopods 3 to 5 bears four setae on the inner margin.

The first coxal plate is about twice as deep as wide; front margin concave with narrowly rounding lower front angle; lower margin evenly rounding without any posterior angle and sparsely beset with short setae. Second coxal plate longer than the first with lower margin evenly rounding and bearing a few short setae. Third coxal plate very much like the second. These first three coxal plates bear on the lower margin a group of three closely set setae which are about twice the length of the rest. The fourth coxal plate is nearly as wide as deep with short setae throughout the lower and hind margins, but without the group of three longer setae.

The three metasome segments with their lower posterior angles slightly produced, though in the male specimen that I have designated as the type the lower posterior corner of the third segment is rather evenly rounding with only a mere suggestion of the angle, but this undoubtedly is only an individual variation. The lower margins of segments 2 and 3 bear a row of short spines with a few spinules higher up. In the specimen figured the hind margin of segment 1 bears one setule, and that of segment 2 bears two setules, while that of segment 3 bears only one which is placed in a shallow notch.

Uropod 1 extending farther back than 2, and uropod 3 not extending back as far as 2. Uropod 2 possesses the sexual variation which

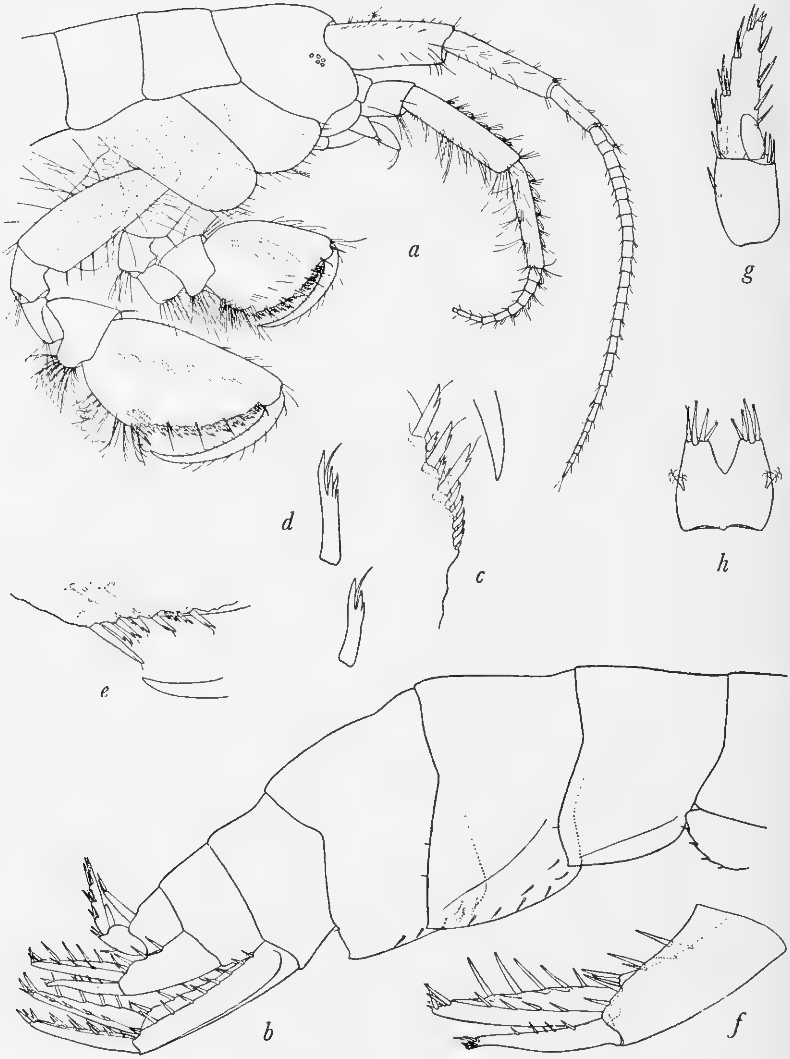

FIG. 7.—*Crangonyx dearolfi,* new species. Male: *a,* anterior end of animal; *b,* posterior end of animal; *c,* part of gnathopod 1 greatly enlarged; *d,* two of the palmar spines greatly enlarged; *e,* part of palm of gnathopod 2 greatly enlarged; *f,* uropod 2; *g,* uropod 3; *h,* telson.

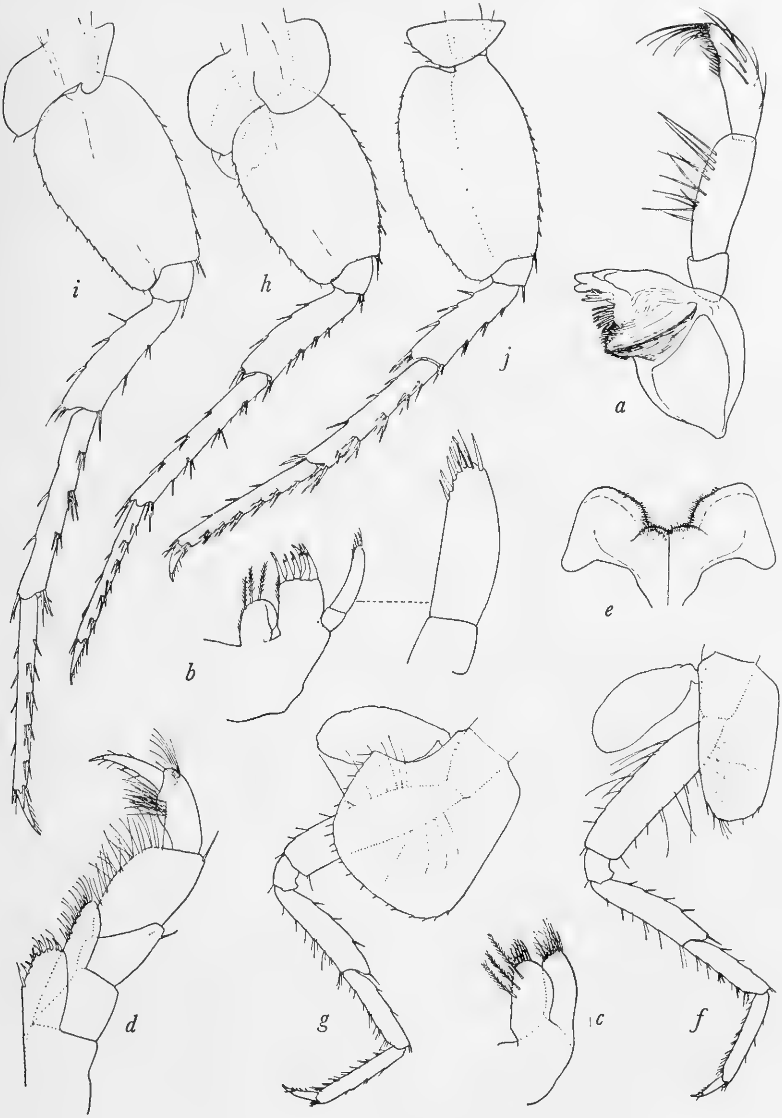

FIG. 8.—*Crangonyx dearolfi,* new species. Male: *a,* mandible; *b,* maxilla 1; *c,* maxilla 2; *d,* maxilliped; *e,* lower lip; *f,* peraeopod 1; *g,* peraeopod 2; *h,* peraeopod 3; *i,* peraeopod 4; *j,* peraeopod 5.

is usual in the genus *Crangonyx.* The outer ramus which is shorter and weaker than the inner ends in a narrowly rounding lobe which has a tendency to bend downward. The peduncle, which is equal in length to the inner ramus, bears four stout spines on outer margin, and five on the inner margin, the three at the distal corner being placed together. The outer ramus is armed on the outer edge with four slender spines, on the inner edge with two or three short spinules, and at the apex with a group of two long and three short spines. The inner ramus is armed on the inner margin with five stout spines, on the outer margin with four slenderer spines and distally with the normal group of spines. Uropod 3, peduncle about two-thirds the length of the outer ramus, which bears three groups of spines on the outer margin, four on the inner margin, and two short spines apically; inner ramus about one-third the length of the outer and without spines.

Telson reaching to about the middle of the inner ramus of uropod 3, as wide as long, cleft almost to center, a group of two plumose setae on lateral margins, and the lobes armed distally with four stout spines.

The second and third mesosome segments each bearing a single median cylindrical sternal gill. The sixth and seventh mesosome segments with the usual simple saclike lateral sternal gills and the first metasome segment with a pair of lateral sternal gills. The coxal gills of the last pair of peraeopods are not attached to the inside surface of the coxae, as is normally the case, but arise from the inside surface of the second joint near the upper margin. Length, male, 15 or 16 mm.

Type.—A male from Hobo Cave, Wernersville, Berks County, Pa., July 28, 1938, collected by Kenneth Dearolf, U.S.N.M. No. 78266.

Length of largest female from Hobo Cave, 22 mm.

METANIPHARGUS BEATTYI, new species

FIGURE 9

In 1933 Dr. K. Stephensen (Zool. Jahrb., vol. 64, Nos. 3/5, p. 426, 1933) established the genus *Metaniphargus* from specimens which had been found "in a small pond, lately covered, at the well, at the border of the calcareous area" at Bak Ariba (Hato), Curaçao, in June 1931. It was of great interest to me, upon examining specimens taken from a well at Frederiksted, St. Croix, Virgin Islands, in 1937 by Mr. H. A. Beatty, to find that they belonged to the same genus as the specimens from Curaçao. Upon dissection and study, they proved, however, to represent a new species, which I now designate *Metaniphargus beattyi* in honor of Harry A. Beatty, an ardent collector who

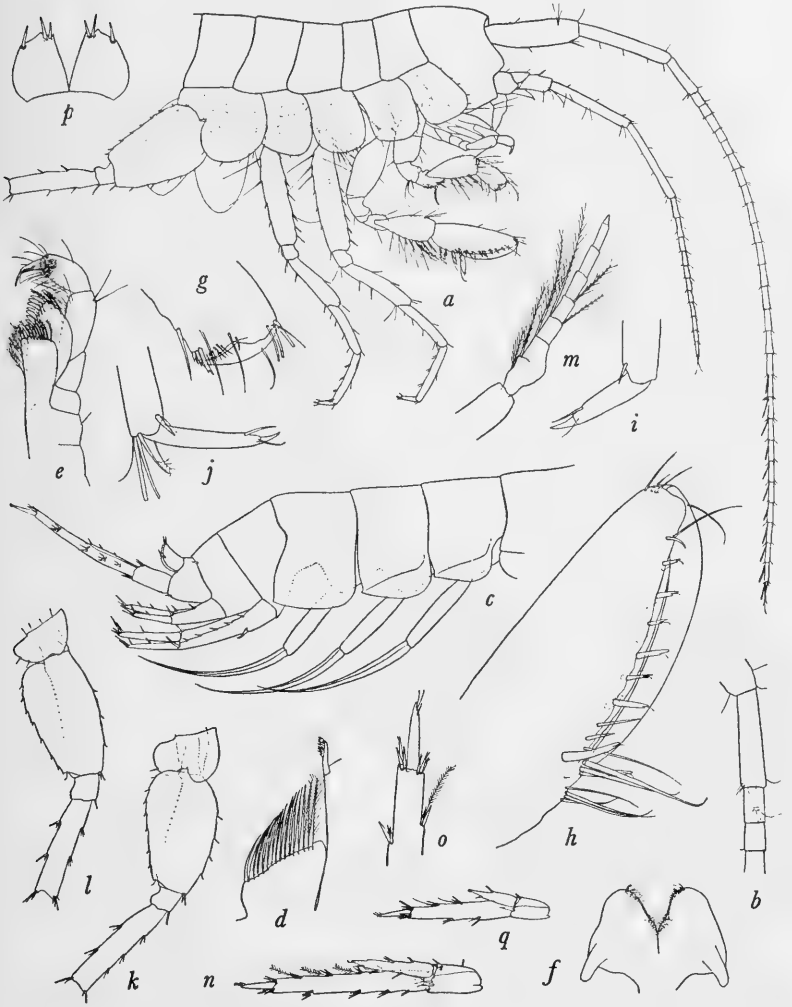

FIG. 9.—*Metaniphargus beattyi,* new species. Male: *a,* anterior end of animal; *b,* accessory flagellum greatly enlarged; *c,* posterior end of animal; *d,* inner plate of maxilla 1; *e,* maxilliped; *f,* lower lip; *g,* distal end of gnathopod 1 greatly enlarged; *h,* distal end of gnathopod 2 greatly enlarged; *i,* seventh joint of peraeopod 2 greatly enlarged; *j,* distal end of peraeopod 3 greatly enlarged; *k,* peraeopod 4; *l,* peraeopod 5; *m,* pleopod 3; *n,* uropod 3; *o,* end of outer ramus of uropod 3; *p,* telson. Female: *q,* uropod 3.

has given many fine specimens of Crustacea to the United States National Museum.

Male.—Head, lateral lobes rather shallow and rounding; eyes absent. Antenna 1 nearly as long as body, first joint about equal in length to the second which is over twice as long as third; flagellum about twice as long as peduncle, and composed of about 26 joints, the distal third of which bear club-shaped sense organs; accessory flagellum composed of 1 long and 1 very short terminal joint, and not as long as the first joint of primary flagellum. Antenna 2 perhaps a little over half the length of antenna 1, fourth and fifth joints about equal in length, flagellum shorter than the peduncle and composed of about 11 joints which are without sense organs.

Right mandible as figured by Stephensen for *M. curasavicus.* Left mandible, first spine of spine row with distal end expanded, the following spines curved and plumose; molar without seta. Maxilla 1, inner plate broad and bearing 15 plumose setae; Dr. Stephensen says that in *M. curasavicus* the inner plate is narrow with 3 apical setae, which is very different from the present species. Maxilla 2 as figured by Stephensen for *M. curasavicus.* Maxilliped, inner plate a little shorter than outer and armed on distal margin with two spine teeth and a row of plumose spines; outer plate reaching nearly to the end of the second palp joint, and armed on the upper inner margin with a row of closely set spine teeth; third joint of palp nearly as long as second; fourth joint bearing nail and a row of very fine setules.

Gnathopod 1, fourth joint armed on the hind margin with a long, curved serrate spine; fifth joint longer but very little wider than sixth; sixth joint not quite twice as long as wide, palm transverse, slightly convex and very finely dentate, passing into the hind margin of joint by an evenly rounding curve which bears three notched spines; seventh joint as long as palm, but not fitting against it closely. Gnathopod 2 considerably stronger than 1, fifth joint shorter but about as wide as sixth; sixth joint long and oval, palm very oblique and passing gradually into the hind margin of joint, defined by two stout spines and a group of long slender spines, armed on outside margin with about seven notched spines and on the inside margin with five or six; seventh joint as long as the palm and fitting snugly against it when closed.

Peraeopods 1 and 2 slender and alike in size and structure; seventh joints straight and bearing two setae at the base of the short nail. Peraeopod 3 with second joint only moderately expanded as in *M. curasavicus;* seventh joint slender, very slightly curved, and bearing two setae at the base of the short nail. Peraeopods 4 and 5 have the fifth to seventh joints missing in all specimens, but the second, third, and fourth joints resemble those of peraeopod 3. Coxal plates 1 to 5 about as deep as their segments, fourth not excavate behind; fifth as deep as fourth and with front lobe much deeper than hind lobe.

Metasome segments each with lower hind corner minutely produced. Uropod 1 reaching back slightly farther than 2, peduncle longer than rami and bearing a stout spine on lower margin about a third the distance from the base; outer ramus shorter than inner. Uropod 2, peduncle slightly longer than inner ramus which is longer than the outer ramus. Uropod 3 longer than 1 and reaching back much farther, peduncle about one-third as long as the first joint of outer ramus; outer ramus twice as long as inner, first joint bearing groups of marginal spines, and those of the inner margin each bearing a plumose seta; second joint about one-fourth the length of the first and bearing apically three minute setules; inner ramus slender and bearing marginal spines. Pleopods well developed. Pleopod 3, outer ramus with a low lobe or swelling on inner margin near the base. The gills are simple, large, and oval and attached to the coxal joints of gnathopod 2 and peraeopods 1 to 4 by a well-developed stalk as in *M. curasavicus*. No sternal gills are present. Telson nearly twice as wide as long, cleft to base with each lobe bearing apically two spines, lateral margins very convex and each bearing a spine near the distal end. Length of male 5 mm.

The female is like the male except that the palm and seventh joint of gnathopod 2 are apparently a little shorter, and uropod 3 is a little shorter. Length of female about 5 mm.

Twelve specimens were taken at the type locality, Frederiksted, St. Croix, Virgin Islands, from slightly brackish spring water in a deep well. One of these specimens, a male, U.S.N.M. No. 80027, is the type.

SYNPLEONIA PIZZINI Shoemaker

Figures 10, 11, 12

Synpleonia pizzini Shoemaker, 1938, Proc. Biol. Soc. Washington, vol. 51, p. 137.

The type locality for this species is a small spring known as Wetzel's Spring, on the side of a hill in Glover-Archbold Park just west of Georgetown, D. C. It is a blind subterranean species which occurs at the surface of the earth only where the underground waters emerge as springs, seepages, and wells. A fully mature female was taken from a well on an island in the Potomac River about a mile above

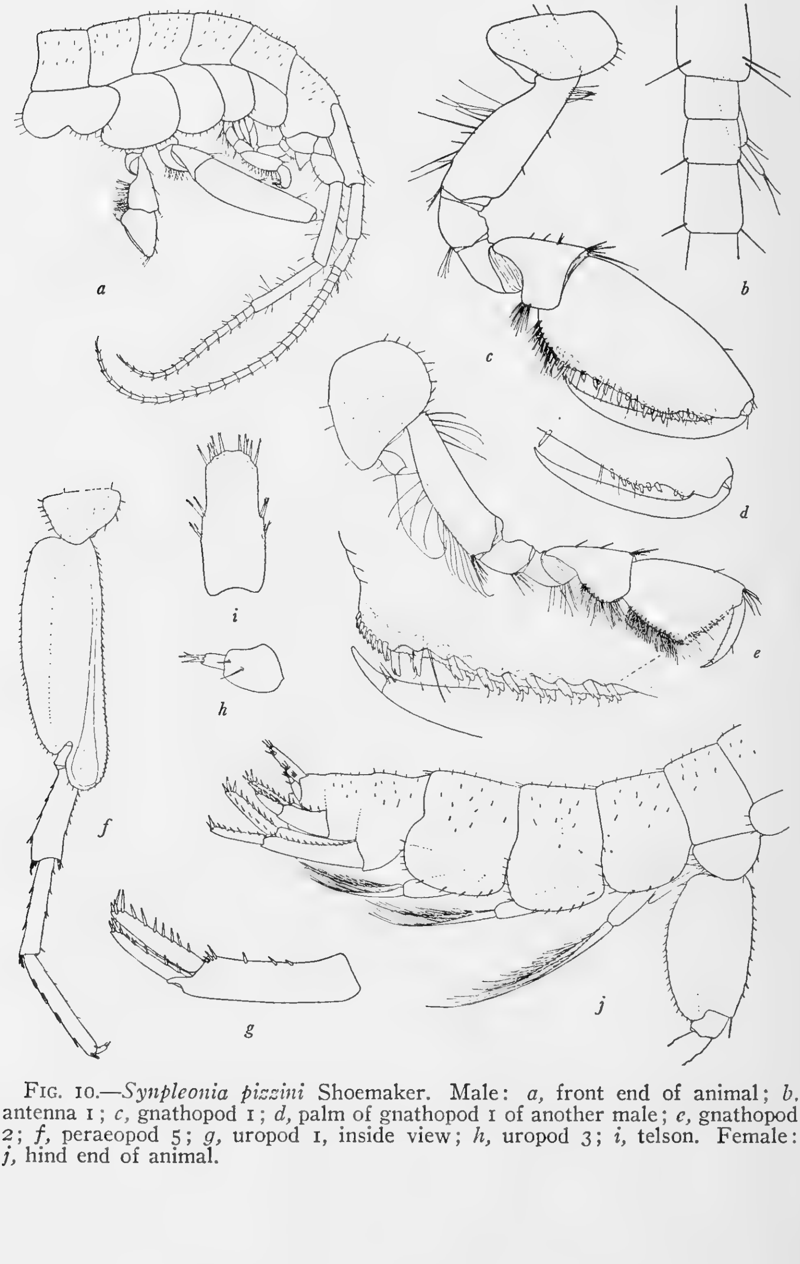

FIG. 10.—*Synpleonia pizzini* Shoemaker. Male: *a,* front end of animal; *b,* antenna 1; *c,* gnathopod 1; *d,* palm of gnathopod 1 of another male; *e,* gnathopod 2; *f,* peraeopod 5; *g,* uropod 1, inside view; *h,* uropod 3; *i,* telson. Female: *j,* hind end of animal.

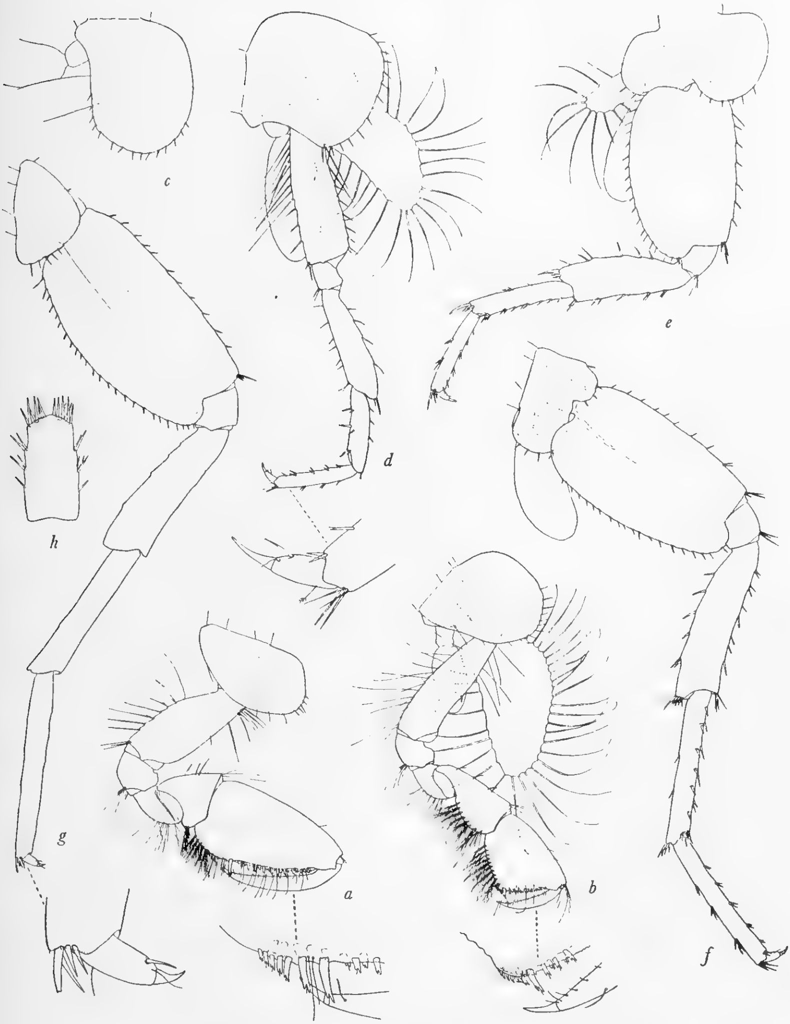

FIG. 11.—*Synpleonia pizzini* Shoemaker. Female: *a*, gnathopod 1; *b*, gnathopod 2; *c*, coxal plate of peraeopod 1; *d*, peraeopod 2; *e*, peraeopod 3; *f*, peraeopod 4; *g*, peraeopod 5; *h*, telson.

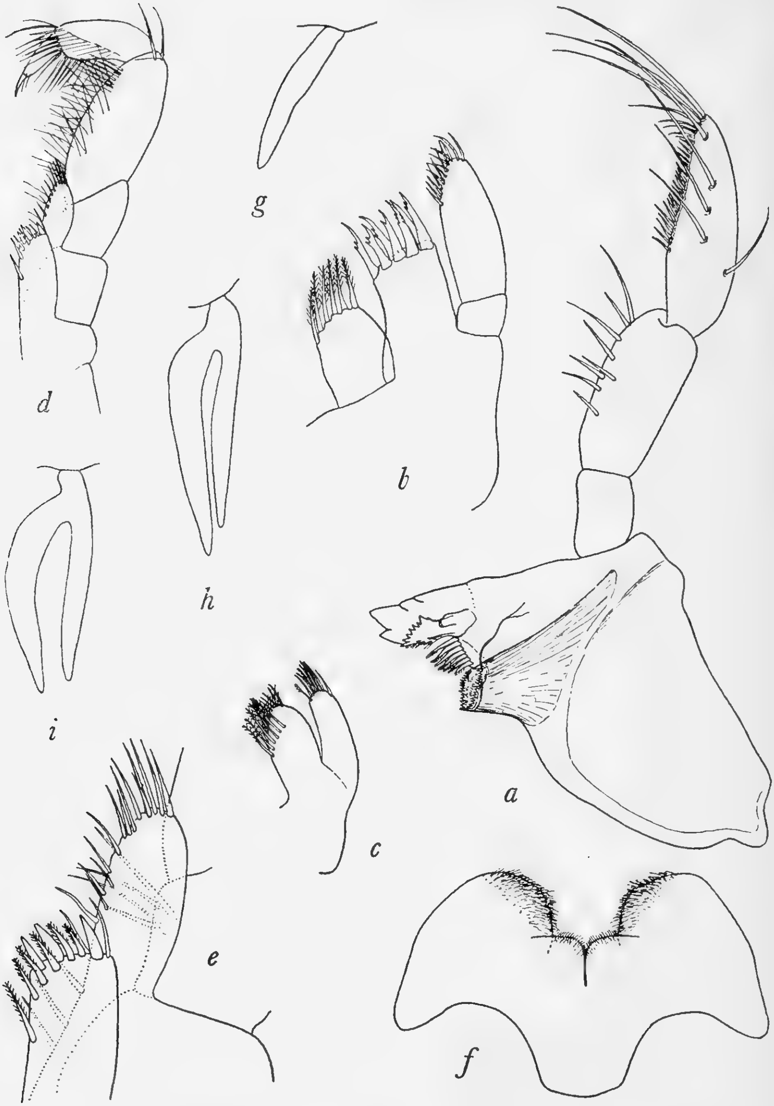

FIG. 12.—*Synpleonia pizzini* Shoemaker. Female: *a,* mandible; *b,* maxilla 1; *c,* maxilla 2; *d,* maxilliped; *e,* inner and outer plates of maxilliped, greatly enlarged; *f,* lower lip; *g,* median sternal gill of second thoracic segment; *h,* bifurcate lateral sternal gill of sixth thoracic segment; *i,* bifurcate lateral sternal gill of seventh thoracic segment.

Cabin John Bridge, Md. As this island is composed of rock and sand, it was thought that the well was supplied by seepage water from the river, until the discovery of this specimen of *Synpleonia pizzini* which proved that the water was derived from a subterranean vein.

Synpleonia pizzini has been taken in Virginia in a spring near Scott Run, and a spring at Bullneck Run, Fairfax County, and from a well the locality of which is not given. In Pennsylvania it has been taken in Refton Cave, and in the seepage of subterranean water in Lancaster County; at Johnson (Upper) Cave, Center County; at Barton Cave and Dulany Cave, Fayette County; and from a small walled spring new New Centerville, Chester County.

As far as known, this species appears to have a rather restricted range and has, up to the present time, been taken only in the District of Columbia, Virginia in the vicinity of Washington, and southern Pennsylvania. The genus *Synpleonia,* however, has a wide range and is represented by a number of species which are differentiated by rather obscure and subtle characters which are more difficult to express in words than in drawings. I am, therefore, figuring *S. pizzini,* in order that its characters may be presented in a more exact and graphic form.

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FAUNAL CONTENT OF THE MARYVILLE FORMATION

BY
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Curator, Division of Stratigraphic Paleontology
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Curator, Division of Stratigraphic Paleontology, U. S. National Museum

Middle Cambrian rocks crop out the full length of the Appalachian Valley. Throughout Maryland and Virginia as far south as the New River there is only the one outcrop belt next to the Blue Ridge. In it lithologic distinctions are hard to recognize, since all the beds are mainly limestone, and fossils are few and far between. Although it is believed that the full Middle Cambrian sequence is present, all the strata are grouped in the Elbrook formation. From the New River southwestward to central Alabama somewhat similar conditions obtain in the Blue Ridge belt, but faults bring up Cambrian beds to the west, forming numerous other outcrop belts. In some of them lithologic distinctions render it easy to recognize three formations.

As I pointed out in 1938 (p. 12), even though the type locality for the Maryville is in another belt to the southwest, it is customary to use the outcrop belt at Rogersville, Tenn., as the standard of comparison. There, not only the Rutledge and Rogersville formations, but also the Maryville, possess clear-cut lithologic characteristics, and their boundaries are so well defined that no doubt remains as to their identity and limits. Furthermore, both the Rutledge and Rogersville formations are fossiliferous, which eliminates confusion on that score.

Northwestward from the Rogersville region, with its ideal conditions, the shale constituents of the Rutledge practically vanish and the Rogersville becomes a limestone with very minor shale intercalations. Therefore, in the most western Cambrian outcrop belt of southwestern Virginia, the three Middle Cambrian formations lose their identity in the Honaker limestone, which is evidently equivalent to the Elbrook formation cropping out farther north and east. Southwestward from central Tennessee increase of shale content in the Middle Cambrian rocks of all the outcrop belts, except that of the Blue Ridge, causes the entire series to resemble, and become difficult to separate on lithologic grounds from, the Upper Cambrian Nolichucky shale. Consequently, Middle and early Upper Cambrian beds are mapped as the Conasauga shale. In my opinion, however, after adequate base maps are supplied and the faunas are thoroughly studied, advantage can be taken of slight lithologic variations to distinguish the several formations now grouped in the Conasauga.

From this brief summary of distribution it is apparent that the Maryville formation is readily recognizable in typical limestone development between more shaly formations, only in certain outcrop belts from the New River in southwestern Virginia to central Tennessee. It should be added that, where the lithologic alterations take place and separate formations cannot be recognized, the total thickness remains about the same, indicating thereby that all formations are still represented. From the studies on which this paper is based, it is now possible to recognize the fact that the Maryville formation is represented in the Conasauga, and it is possible to refer rocks to it on the basis of faunal content.

At its type locality (Keith, 1895) the Maryville formation is described as consisting of 150 to 550 feet of massive blue limestone, with little change in appearance except for frequent earthy, siliceous bands and occasional grayish-blue mottled beds. In the Estillville quadrangle, where the name was first introduced, Campbell (1894) describes the formation as consisting of 550 to 650 feet of comparatively pure, heavy-bedded blue limestone, carrying large masses of chert in the southeastern part of the quadrangle. Little more has been written about the formation, chiefly because it has not been recognized except when found as a typical limestone development in the area previously outlined.

No organic remains, except calcareous algae, have been found in the Maryville formation where it is typically developed as a rather massive limestone. Algal deposits in any formation possess more or less pronounced characteristics, which permit their use in the same manner as any other fossils, but insufficient study has been given in most cases to render them useful for precise correlation. Thus far the algal deposits of the Maryville limestone have been used only in field work for tracing beds in limited regions. Size, shape, and characteristics of silicification are the criteria usually relied upon for this work. Since trilobites or other animal remains were not found in the heavy Maryville limestone beds, the impression went out that the formation is unfossiliferous, and for many years this idea prevented recognition of the fossils that were in hand from the formation. About 1934 faunas were reported from sections where all agreed that the containing beds represent the Maryville formation. From then on thought was given to the possibility that correlation of fossils from beds with nontypical lithologic development would permit their reference to the Maryville. I hinted at this possibility in 1938 (p. 13) when I found that if the strike was crossed in a northwesterly direction at several places in the Coosa Valley, Ala., Rutledge and Rogersville fossils turned up in normal succession, and beyond them other faunas of presumably younger age, but still beneath the Nolichucky equivalents. At that time certain studies of western North American collections had not yet been made, and I could not be sure of my conclusions. In 1940 it was possible to prove the late Middle Cambrian age of these western faunas, thus providing a basis for further studies in the Appalachians.

Lithologic changes from the clearly defined formations of the Rogersville region to the Honaker limestone on the one hand, and to the Conasauga shale on the other, are not abrupt. In the one direction the limestone content increases at the expense of the shale constituents, while in the opposite direction conditions are reversed. To a worker in the Cambrian it is not strange, therefore, that animal remains were discovered in the Maryville formation where shaly elements are first introduced. Incidentally, it may be mentioned in passing that those of us who are accustomed to collecting from Cambrian rocks seldom search long for fossils in massive limestones or dolomites. Experience has taught us that fossils are to be had only in certain types of crystalline limestone, and almost universally in limestone nodules or thin irregular limestone layers in shale, or in thin shale layers between massive limestones. Massive shales also generally lack fossils, but if they do occur, they are abundant and usually include many examples of entire trilobites.

Furthermore, it is well not to forget that for many years numerous Nolichucky species were referred to the Maryville, and until they could be reassigned to their true stratigraphic position, they served merely to obscure the picture. A few linguloid brachiopods were reported from thin shale seams in the upper part of the Maryville limestone northwest of Morristown, and at a few other localities. These fossils are of so little value for correlation purposes that little attention was paid to them. In 1934 Hall and Amick found a small lot of fossils in thin shale bands in the Maryville along Forked Deer Creek, where it cuts through Copper Ridge west of Clinch Mountain (U. S. 25). These fossils were described by me in 1938. As they were recognized as being altogether new, they could not be used for correlation purposes, particularly since they were known from only one spot.

Step by step our understanding of the true stratigraphic position of the Rutledge, Rogersville, and Nolichucky species became clear, and fossils were being found in unquestioned Maryville, with the result that a direct approach to the problem was possible. After acquiring some knowledge of the late Middle Cambrian faunas in the Cordilleran region, and comparing them with those found definitely in the Maryville formation on Clinch Mountain, the idea that the *Olenoides* and possibly other faunas of the Conasauga shale were of the same age gained in appearance of validity. The fauna obtained from the railroad track east of Heiskell, Tenn., was relocated and the section reexamined. It seemed that these fossils came from the Maryville formation without reasonable doubt. At this point further field investigation was called for, and arrangements were accordingly made to examine the outcrops in the Cambrian belt at the western base of Clinch Mountain, beginning in the north with the Forked Deer Creek section and making traverses along all roads crossing the strike, until it could be proved what really happened to the beds clearly recognizable in the northern part of the belt. This work was carried out in May 1941.

Beginning with the Forked Deer Creek section, the roads across Copper Ridge were traversed one after another. It was rather easy to recognize the Rutledge, Rogersville, and Maryville formations, overlain by typical Nolichucky strata, in every section for at least 20 miles. Unfortunately, no fossils were found in the Maryville in these sections. Of course, not much success was expected in this direction, because only where rather deep new road cuts are made is it possible to pick up the softer fossiliferous beds in such deeply weathered rocks as are the rule in the region. For many more miles the outcrops are less satisfactory owing to the fact that the area is farther from the Clinch River, but it is possible to trace the existence of the several formations by topographic expression and from restricted, deeply weathered rock outcrops. No time was given to the search along this portion of Copper Ridge.

Investigations were then centered about the outcrops west of Knoxville. As previously stated, study of the collection obtained in 1885 from along the railway tracks east of Heiskell, 11 miles northwest of Knoxville, and for many years referred, along with other fossils in similar limestone, to the Nolichucky formation, had raised the question of its age. Reexamination of that section proved conclusively that this fauna occurs in the lower half of the Maryville formation, which here includes considerable shale. Next, the new face of the road cut on the Clinton Highway (U. S. 25W) near Bull Run, 13 miles west of Knoxville, was examined. There two faunas were found, adding the data necessary for the conclusive assignment of faunas from the Conasauga in northwestern Georgia and Alabama to the Maryville. Since the section along the highway west of Knoxville lies in the area in which the formations were mapped as Conasauga, it is only a small step to the reassignment of the faunas from Georgia and Alabama.

In Hall and Amicks' section on Forked Deer Creek the 455 feet of Maryville is composed almost entirely of limestone. Of this total thickness about 36 feet is described as shaly, about 12 feet is called impure, owing to argillaceous bands or mottling, and only about 30 feet is recorded as shale; even in the thin bands of shale, limestone lenses and layers are present. At several horizons mention is made of wavy lines. Downstream to the west of highway U. S. 25 the Rutledge is very well exposed, because the Clinch River cuts down the dip of the Rome shales against the Rutledge. Steep slopes above the limestone cliffs cause the soft Rogersville to crop out nearly everywhere, and above it the rather massive Maryville limestone. In Owl Hollow, about 1 mile west of the bridge over which route 25 crosses the Clinch River, the Rutledge is well exposed. Here it is a very dark blue massive limestone, irreglularly mottled with argillaceous shale, but has a conspicuous limestone layer about 40 feet thick. This limestone has the same wavy, banded and mottled appearance as the Rutledge limestone. In this section the lower 250 feet of the Maryville consists of heavy blue limestone, most of which is "wormy," or ribboned like the Rutledge. Above this about 50 feet of rock is more shaly, with bands up to 10 inches thick of almost pure argillaceous shale. Such shale bands appear again in augmented quantity in the upper part of the formation. Much of the limestone in the upper third of the formation is ribboned. The same conditions characterize the Notchy Creek and Puncheon Camp Creek sections farther west.

No other sections are available, owing to the deep weathering and lower relief between Puncheon Camp Creek and the railroad cut south of Heiskell, more than 30 miles to the southwest. The Heiskell section extends along the railway, beginning at the eastern edge of the flood plain of Bull Run, which is cut into the Rutledge and Rogersville. It was observed that shale content increases in the sections west of Clinch Mountain and Copper Ridge as one goes southwestward, which in part explains the wider stream valleys and the lowered ridges. At Heiskell the shale content has increased until the Maryville resembles the Rogersville and Nolichucky so much that it may be mistaken for either of them. Layers of limestone pebble conglomerate, with the pebbles separated by matrix, and a few thin zones of edgewise conglomerate, were observed. Layers of oolitic limestone are rather common, one of them yielding the *Eteraspis* fauna.

Near Bull Run, 13 miles west of Knoxville on the Clinton road (U. S. 25W), recent widening of the highway has exposed a large face of the Maryville formation. About 370 feet of beds were measured. Unfortunately, the base is not exposed and one cannot be sure of the logical point at which to draw the Maryville-Nolichucky boundary. Although the rock in this cut is fresher than the outcrops usually to be seen, yet the limestone content is far less than the shale. Edgewise and pebble beds are common, and many of the limestone layers are clearly lenses. Oolitic beds are common. Nearly all the shale, whether in beds or as partings between limestone layers and lenses—without regard to the type of limestone—is micaceous and fucoidal, a condition which generally precludes the existence of fossils. About 40 feet above the base, as exposed, several small nodules yielded *Lingulella* species and *Alokistocare* cf. *projectum* Resser. A little more than 30 feet higher in the section the *Eteraspis* fauna occurs in the thin-bedded limestones with shale partings, associated with more massive, oolitic crystalline limestone, containing patches of *Girvanella*. The fossiliferous nodules and layers contain vaughnite in the form of pebbles and irregular masses, often sharply brecciated. Thus it will be observed that these faunas are found in the lower fourth of the formation as here exposed.

A similar section occurs on Spring Branch near Bakers Mill, about halfway between U. S. 25W and the Heiskell section.

We have now outlined the regional distribution of the Maryville formation where it can be recognized by lithologic characteristics, and have shown the faunal content where it undergoes lithologic change in one outcrop belt. This tracing along Copper Ridge has carried the formation into the typical Conasauga development. Future field work should enable us to trace the formation farther in the Copper Ridge, and into other belts as well, but sufficient data are now in hand to suggest the major Maryville faunas at least.

The faunal alignment seems to be somewhat as follows. Relying on the position of the *Alokistocare* and *Eteraspis* faunas in the Heiskell and Clinton road sections, it seems that they are in the lower third of the formation. On the other hand the *Perioura* fauna seems to occur in the lower part of the upper third. In the assignment of species to the Maryville from among those in the Conasauga of Georgia and Alabama, the only possibility is to take collections as a whole, when they contain forms known to represent the Maryville. On this basis the following lists are constructed.

TENNESSEE

Forked Deer Creek (lower part of upper third of formation):
Deltophthalmus halli Resser
Lingulella sp.
Perioura masoni Resser
Proagnostus maryvillensis Resser

Heiskell section (presumably lower third of formation):
Acrotreta sp.
Eteraspis crassa (Resser)
Eteraspis glabra (Walcott)
Hyolithes sp.
"*Olenoides*" sp. and a new trilobite genus

Bull Run, 13 miles northwest of Knoxville:
40 feet above base (as exposed)—
Alokistocare cf. *projectum* Resser
Lingulella sp.
About 30 feet higher—
Alokistocare cf. *americanum* (Walcott), and two other species
Eteraspis glabra (Walcott)
"*Olenoides*" sp.

GEORGIA

Livingston (loc. 89x); chert nodules and shale:
Alokistocare americanum (Walcott)
Alokistocare georgense Resser
Alokistocare projectum Resser
Amecephalina coosensis Resser
Chancelloria drusilla Walcott

ALABAMA

South of Yanceys Bend of Coosa River, near Blaine, 3 miles east of Center, Ala. (loc. 90x); cobbles in shale:

Acrocephalops granulosa Resser
Acrothele bellula Walcott
Acrotreta kutorgai Walcott
Alokistocare americanum Walcott
Alokistocare angustatum Resser
Alokistocare blainense Resser
Alokistocare centerense Resser
Alokistocare lingulum Resser
Amecephalina bella Resser
Amecephalina convexa Walcott
Armonia elongata Walcott
Blainia centerensis Resser
Brooksella alternata Walcott
Ehmania smithi (Walcott)
Ehmaniella antiquata (Salter)

Eteraspis gregaria (Walcott)
Eteraspis paula (Walcott)
Hyolithes partitus Resser
Kochaspis coosensis (Walcott)
Laotira cambria Walcott
Lingulella hayesi (Walcott)
Micromitra alabamaensis (Walcott)
Olenoides curticei Walcott
Pelagiella blainensis Resser

1 mile northeast of Moshat, about 5 miles southeast of Center, Cherokee County, Ala. (loc. 112); shale containing nodules:

Acrocephalops insignis (Walcott)
Acrocephalops nitida Resser
Elrathia alabamensis Resser
Eteraspis paula (Walcott)
Euryrhachis ? centerensis Resser
Perioura typicalis Resser

It is possible that other faunas in hand may belong in the Maryville besides these here given the new assignment.

If the foregoing faunal assignments are sound, the Maryville formation is to be regarded as more or less exactly equivalent to the Bloomington formation of the Wasatch region, the Marjum of the House Range, and the Eldon of the Canadian Rockies.

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The Presidential Cruise on the U.S.S. *Houston* to the eastern tropical Pacific and the Caribbean Sea in 1938 obtained a most interesting collection of Amphipoda through the indefatigable labors of Dr. Waldo L. Schmitt, the naturalist of the expedition, who had the most enthusiastic assistance of the ship's personnel throughout the cruise. The bulk of the material was obtained on the west coast of Lower California. At Magdalena Bay, Lower California, amphipods were found to be exceedingly abundant. When water was added to a half tubful of sand brought up with a boat dredge at station No. 3-38 an amazingly thick "scum" of amphipods rose to the surface. With a fine sieve a solid quart of these small crustaceans was skimmed off with little difficulty. The bulk of this material consisted of a new species, *Neomegamphopus roosevelti,* which required a new genus for its reception. A total of 27 different species, belonging to 24 genera, appeared in this haul.

Other species were taken at Clipperton Island between 600 and 700 miles off the west coast of Mexico, at Cocos Island, and at the Galápagos Islands, which lie across the Equator. The discovery of *Orchestia marquesana* at Clipperton Island is of more than passing interest, as that locality is far to the northeast of its previously known occurrence. At first I thought a new but related species was involved, but soon found that the differences were due to the secondary sex characters found in the male. Dr. Stephensen, who described the species, possessed only females; both sexes are represented in the collection from the Presidential Cruise.

After passing through the Panama Canal, the *Houston* made a brief stop at Old Providence Island off the east coast of Nicaragua, where three species were obtained.

The collection comprises 27 genera, 36 species, and one variety. Included are 10 new species and one new variety, as follows:

Orchomenella magdalenensis, n. sp.
Gitanopsis pusilloides, n. sp.
Microdeutopus schmitti, n. sp.

Photis spinicarpa, n. sp.
Photis brevipes, n. sp.
Eurystheus spinosus, n. sp.
Podoceropsis dubia, n. sp.
Neomegamphopus roosevelti, n. sp.
Parajassa angularis, n. sp.
Microjassa macrocoxa, n. sp.
Eurystheus tenuicornis var. *lobata*, n. var.

Following is a list of stations with species encountered:

Station No. 1-38. Cedros Island, off west coast of Lower California. Shore collecting, both north and south of cannery, east side of island. Amphipods from under drifted kelp on gravel beach to north, July 17, 1938.

	No. of specimens
Orchestia traskiana Stimpson	Many

Station No. 2-38. Cedros Island, off west coast of Lower California. Bottom sample in 24-25 fathoms, about one-fourth of the way from shore to anchorage, July 17, 1938.

	No. of specimens
Batea catharinensis Müller	1

Station No. 3-38. Magdalena Bay, Lower California, inside northern point of entrance to bay, between Belcher Point and anchorage, 10-15 fathoms; sandy, weedy bottom, July 18, 1938.

	No. of specimens
Orchomenella magdalenensis, n. sp.	6
Aruga dissimilis (Stout)	2
Ampelisca schellenbergi Shoemaker	20
Platyischnopus gracilipes Schellenberg	1
Gitanopsis pusilloides, n. sp.	34
Batea catharinensis Müller	Many
Maera simile Stout	2
Elasmopus rapax Costa	5
Orchestia traskiana Stimpson	1
Hyale frequens (Stout)	15
Lembos (*Bemlos*) *macromanus* (Shoemaker)	Many
Microdeutopus schmitti, n. sp.	11
Photis spinicarpa, n. sp.	16
Photis brevipes, n. sp.	30
Eurystheus tenuicornis (Holmes)	1
Eurystheus tenuicornis var. *lobata*, n. var.	25
Eurystheus spinosus, n. sp.	11
Neomegamphopus roosevelti, n. sp.	Many
Chevalia aviculae Walker	5
Ampithoe plumulosus Shoemaker	15
Ampithoe ramondi (Audouin)	16
Jassa falcata (Montagu)	3

	No. of specimens
Parajassa angularis, n. sp.	3
Microjassa macrocoxa, n. sp.	30
Ericthonius brasiliensis (Dana)	Many
Cerapus tubularis Say	2
Podocerus cristatus (Thomson)	12
Caprella scaura Templeton	Many

Station No. 4-38. Magdalena Bay, Lower California; filamentous green algae from deeper end of preceding dredge hauls, July 18, 1938.

	No. of specimens
Batea catharinensis Müller	30
Hyale frequens (Stout)	3
Lembos (Bemlos) macromanus (Shoemaker)	Many
Microdeutopus schmitti, n. sp.	1
Photis brevipes, n. sp.	1
Eurystheus tenuicornis (Holmes)	2
Eurystheus tenuicornis var. *lobata*, n. var.	1
Neomegamphopus roosevelti, n. sp.	Many
Ampithoe plumulosus Shoemaker	1
Microjassa macrocoxa, n. sp.	1
Podocerus cristatus (Thomson)	1
Caprella scaura (Templeton)	Many

Station No. 5-38. Cape San Lucas, Lower California. Off Punta Gorda, off rocky shore to west and San Jose del Cabo Bay, dredged in 6-10 fathoms, July 19, 1938.

	No. of specimens
Lembos (Bemlos) macromanus (Shoemaker)	1
Microdeutopus schmitti, n. sp.	1
Neomegamphopus roosevelti, n. sp.	6
Ampithoe plumulosus Shoemaker	4
Cerapus tubularis Say	2
Caprella scaura (Templeton)	4

Station No. 9-38. Clipperton Island. Shore collecting on rocks to south of landing place, July 21, 1938.

	No. of specimens
Elasmopus rapax Costa	2
Elasmopus spinidactylus Chevreux	15
Elasmopus gracilis Schellenberg	3
Ampithoe plumulosa Shoemaker	1

Station No. 14-38. Clipperton Island. Debris from two boobies' nests back from landing place, July 21, 1938.

	No. of specimens
Orchestia marquesana Stephensen	Many

Station No. 15-38. Sulivan Bay, James Island, Galápagos Islands. Shore and tide-pool collecting, 3 : 30 to 5 : 00 p.m., tide beginning to run out, July 24, 1938.

	No. of specimens
Ampelisca lobata Holmes	1
Colomastix pusilla Grube	1
Elasmopus rapax Costa	14

Station No. 16-38. Narborough Island, Galápagos Islands. Shore collecting, July 25, 1938.

	No. of specimens
Hyale hawaiensis (Dana)	6

Station No. 22-38. At anchorage off Gardner Bay, Hood Island, Galápagos Islands. Off gangway, dip net, 11 :00 p.m., July 27, 1938.

	No. of specimens
Hyperia bengalensis (Giles)	1

Station No. 28-38. Chatham Bay, Cocos Island. Bottom sample, August 3, 1938.

	No. of specimens
Podoceropsis dubia, n. sp.	23

Station No. 30-38. Old Providence Island, Caribbean Sea. Shore, reef, and tide-pool collecting, August 6, 1938.

	No. of specimens
Ampithoe ramondi (Audouin)	2

Station. Old Providence Island, Caribbean Sea, August 6, 1938.

	No. of specimens
Colomastix pusilla Grube	1
Elasmopus brasiliensis (Dana)	1

GAMMARIDEA

LYSIANASSIDAE

ORCHOMENELLA MAGDALENENSIS, new species

FIGURE 1

Station 3. Magdalena Bay, Lower California, 6 specimens.

Female.—Head, lateral lobes produced, narrowing distally with apex narrowly rounding. Eye large, oval, and with little color. Antenna 1, flagellum composed of five joints; accessory flagellum of two joints. Antenna 2 a little longer than 1, third joint as long as fourth plus half of the fifth; fifth joint a little over half as long as the fourth; flagellum nearly as long as fourth and fifth joints together and composed of six joints.

The epistome projects considerably beyond the upper lip, and is triangular with narrowly rounding apex. Mandible with molar rather prominent; cutting edge with a tooth at outer corner; three spines in

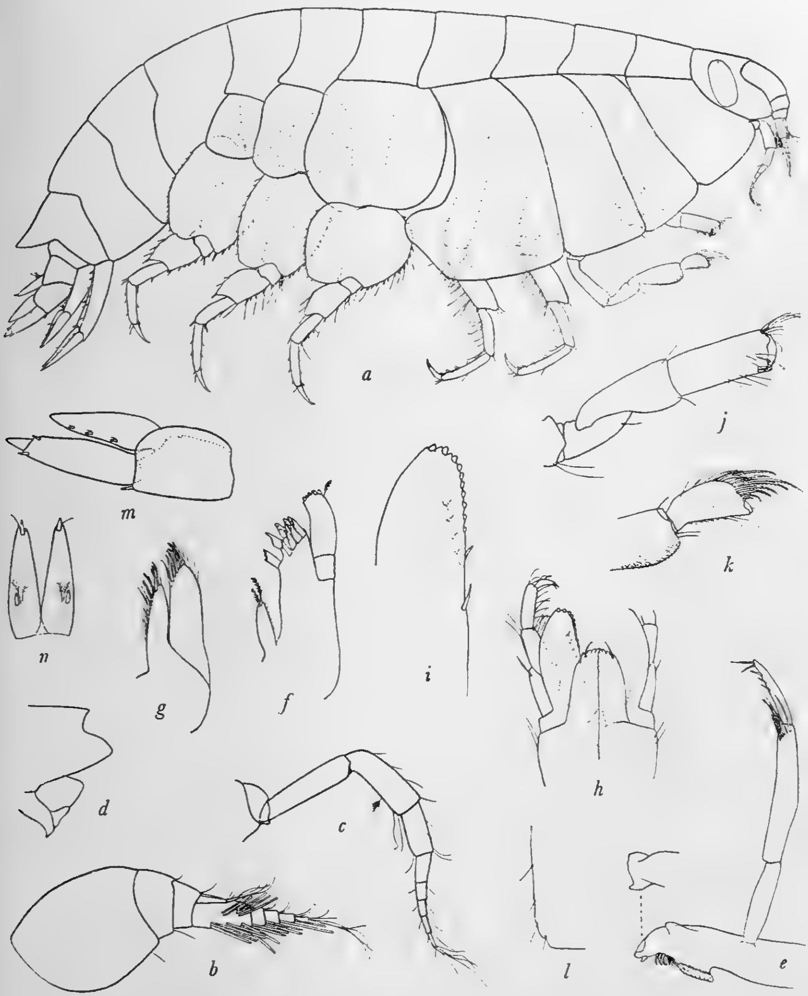

FIG. 1.—*Orchomenella magdalenensis,* new species. Female, *a,* entire animal; *b,* antenna 1; *c,* antenna 2; *d,* head showing epistome and upper lip; *e,* mandible; *f,* maxilla 1; *g,* maxilla 2; *h,* maxillipeds; *i,* outer plate of maxilliped; *j,* gnathopod 1; *k,* gnathopod 2; *l,* hind corner of coxal plate 3; *m,* uropod 3; *n,* telson.

spine row; palp with first joint nearly two-thirds as long as second and longer than third; second joint nearly twice as long as third. Maxilla 1, inner plate about half as long as outer, narrow and bearing two plumose setae apically; outer plate bearing 11 serrate spine teeth; palp armed distally with 5 short, blunt spine teeth and a plumose seta. Maxilla 2, inner plate shorter and narrower than outer. Maxillipeds, inner plate reaching to the middle of the outer and armed distally with three blunt teeth; outer plate reaching nearly to the middle of the third joint of palp, apex and upper part of inner margin armed with short blunt teeth, outer surface bearing an oblique row of short spines which ends in two stout spines on inner margin; palp short and slender, third joint nearly as long as second; fourth joint over half the length of the third, curved and bearing a minute nail.

Coxal plates 1 to 4 much deeper than their segments; first coxal plate noticeably expanded below; second and third with sides nearly parallel; fourth deeply excavate with lower hind lobe prominent and obliquely truncate. Gnathopod 1 slender; second joint as long as the third, fourth, fifth, and sixth together; fifth joint a little wider than, but equal in length to, the sixth; sixth joint with margins parallel and a little over twice as long as wide; palm transverse; seventh joint fitting palm and bearing a tooth on inner margin. Gnathopod 2 very slender and much longer than 1; second joint about twice the length of the third which is equal in length to the fifth; sixth joint half the length of the fifth; seventh joint very short and weak.

Peraeopods 1 and 2 slender and subequal in length. Peraeopods 3 to 5 with second joints considerably expanded, that of 3 wider than long; fourth joints with lower hind corner somewhat produced. Metasome segment 1 with lower margin rounding; segments 2 and 3 with lower hind corner about right-angled. Urosome segment 1 produced backward dorsally into a prominent tooth. Uropod 1 projecting back about as far as 3. Uropod 3 with upper edge of peduncle produced into a thin convex lobe; outer ramus bearing only two short spines which are at the base of the second joint; inner ramus bearing three short spines on outer margin. Telson long and narrow, cleft almost to its base, with each lobe bearing an apical spine and a spine and two plumose setules on upper surface. Length, from front of head to end of uropod 3, about 6 mm.

Type locality.—Magdalena Bay, Lower California, dredged in 10-15 fathoms inside northern point of entrance to bay, July 14, 1938. Holotype, female, U.S.N.M. No. 79370.

This species conforms to the genus *Orchomenella* except in the proportions of the joints of the mandibular palp, and in the proportions of the joints of the peduncle of the second antenna. So far as I am aware, in no other species is the first joint of the mandibular palp longer than the third, or the third joint of the peduncle of antenna 2 longer than either the fourth or fifth. I am, nevertheless, placing the species in *Orchomenella,* owing to its general conformity with that genus, rather than creating a new genus for it.

ARUGA DISSIMILIS (Stout)

FIGURE 2

Nannonyx dissimilis Stout, 1913, Zool. Jahrb., Abt. Syst., vol. 34, p. 638.

Station 3. Magdalena Bay, Lower California, 2 specimens.

This species was described by Vinnie Ream Stout from Laguna Beach, southern California. Although I have seen very few specimens of this species, she says,

> Perhaps the most common of the dwellers of the kelp from deep water was the species, *Nannonyx dissimilis,* n. sp., of which there were hundreds in one holdfast. Besides the fact of their numbers, these forms were rather conspicuous in the bright orange eggs of the females.

These two specimens constitute the second record of the occurrence of this species, and extend the range considerably to the south.

I have transferred this species to the genus *Aruga,* created by S. J. Holmes in 1908 to receive his California species *A. oculata,* as the mouth parts and appendage characters of *A. dissimilis* agree with those of *A. oculata.* I am, however, of the opinion that the genus *Aruga* may become a synonym of the genus *Lysianopsis* created by Holmes in 1905 for the reception of *L. alba* from southern New England, as the characters of the two genera appear to be much the same. The mouth parts of these two genera agree, including the first maxilliped, the inner plate of which bears two terminal plumose setae.

AMPELISCIDAE

AMPELISCA LOBATA Holmes

Ampelisca lobata Holmes, 1908, Proc. U. S. Nat. Mus., vol. 35, No. 1654, p. 517, fig. 25.

Station 15. Sulivan Bay, James Island, Galápagos Islands, 1 specimen.

This species was described by S. J. Holmes from a single specimen which was taken at *Albatross* station 4420, off San Nicolas Island, southern California. There are specimens of this species in the National Museum collection from Catalina Island, Corona Del Mar, and Monterey Bay, Calif., and one specimen from Vancouver Island taken north of Nanaimo. The present record from the Galápagos Islands extends the range about 3,000 miles southward.

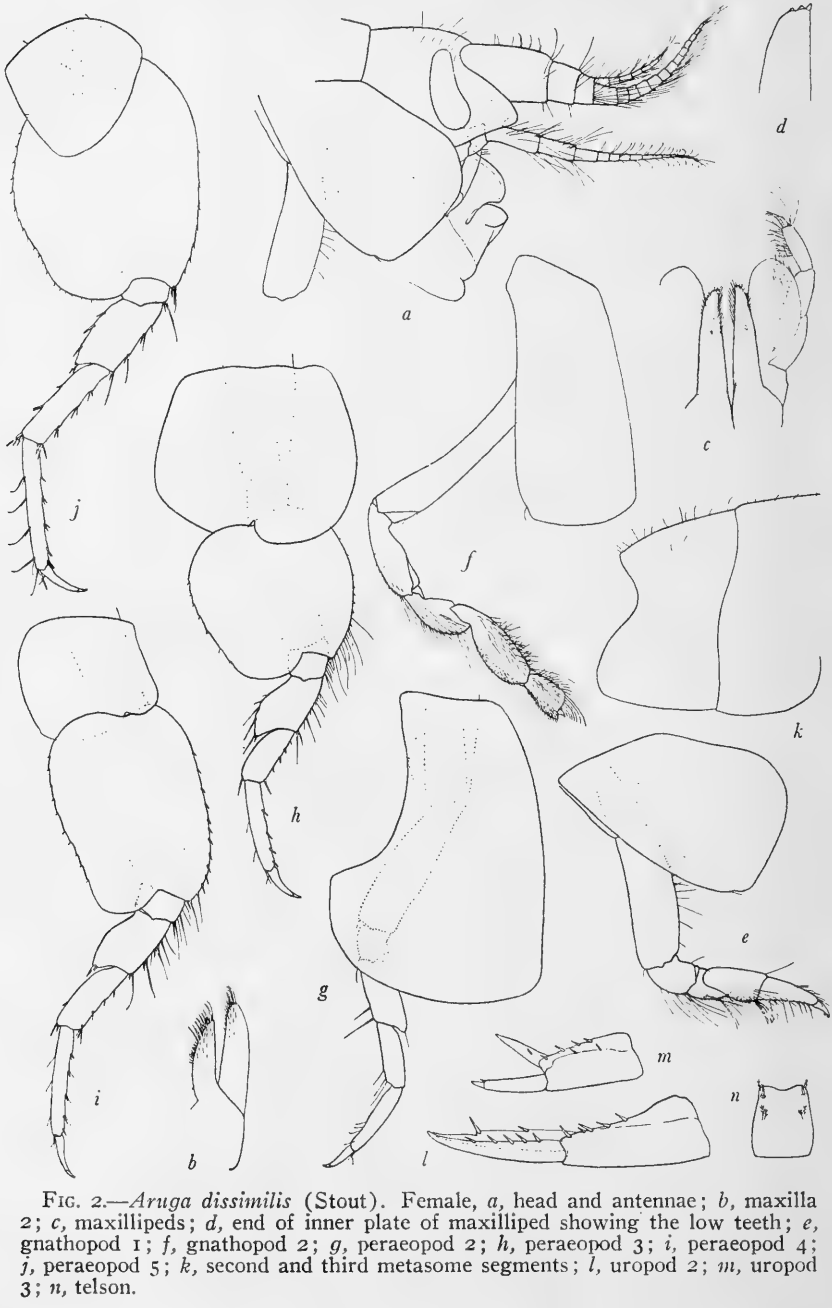

FIG. 2.—*Aruga dissimilis* (Stout). Female, *a,* head and antennae; *b,* maxilla 2; *c,* maxillipeds; *d,* end of inner plate of maxilliped showing the low teeth; *e,* gnathopod 1; *f,* gnathopod 2; *g,* peraeopod 2; *h,* peraeopod 3; *i,* peraeopod 4; *j,* peraeopod 5; *k,* second and third metasome segments; *l,* uropod 2; *m,* uropod 3; *n,* telson.

AMPELISCA SCHELLENBERGI Shoemaker

Ampelisca schellenbergi SHOEMAKER, 1933, Amer. Mus. Nov., No. 598, p. 3, figs. 1, 2.

Station 3. Magdalena Bay, Lower California, 20 specimens.

This species was described from specimens taken by the *Albatross* at stations 2369-2374 in the Gulf of Mexico. There are also specimens in the National Museum collection from the west coast of Florida, the Dry Tortugas, and from off Yucatan. The present specimens are the first recorded from the west coast of America.

HAUSTORIIDAE

PLATYISCHNOPUS GRACILIPES Schellenberg

Platyischnopus gracilipes SCHELLENBERG, 1931, Gammariden und Caprelliden, Swedish Antarctic Exped., 1901-1903, vol. 2, No. 6, p. 63, fig. 33.

Station 3. Magdalena Bay, Lower California, 1 specimen.

This species was recorded by Schellenberg from Valparaiso, Chile, and Rio de Janeiro, Brazil. It is represented in the National Museum collection by a specimen taken by Dr. W. L. Schmitt at La Libertad, Ecuador, when traveling under the Walter Rathbone Bacon scholarship of the Smithsonian Institution in 1934, and by a specimen measuring 7 mm. taken off La Jolla, Calif.

AMPHILOCHIDAE

GITANOPSIS PUSILLOIDES, new species

FIGURE 3

Station 3. Magdalena Bay, Lower California, 34 specimens.

Female.—Head, rostrum rather short, not strongly curved or acute; lateral corners evenly rounding; eyes dark and rather prominent with the peripheral elements usually colorless. Antenna 1 a little shorter than 2; flagellum about half the length of the peduncle and composed of four or five joints. Antenna 2 with flagellum less than half the length of the peduncle and composed of six or seven joints. Upper lip unsymmetrically bilobed.

Mandible, molar very prominent, with what appears to be a chisel-like tooth at the front corner; cutting edge with many teeth; spine row with 11 serrulate spines; palp with third joint equal in length to the second. Left mandible with broad accessory plate having a finely toothed cutting edge. Maxilla 1, inner plate with one spinule; outer plate with seven spine teeth; palp broad, apex armed with two chisel-like teeth and two spinules. Maxilla 2, inner plate a little broader but

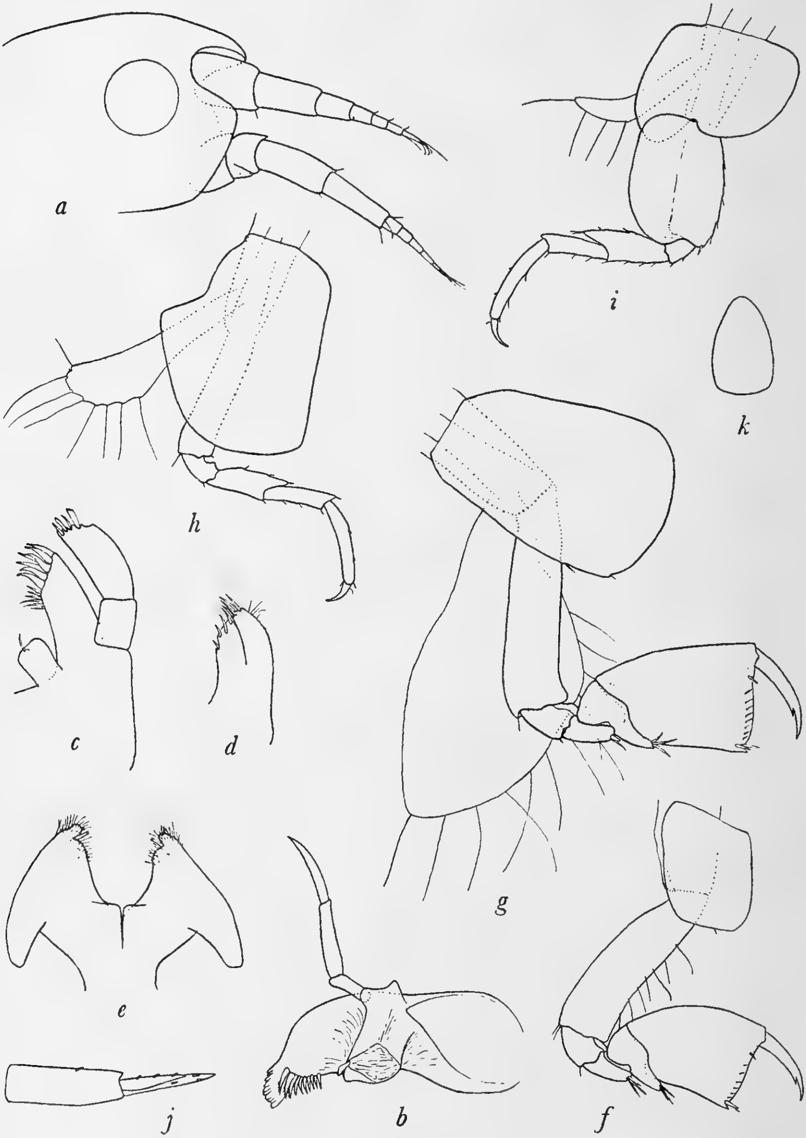

FIG. 3.—*Gitanopsis pusilloides*, new species. Female, *a*, head; *b*, mandible; *c*, maxilla 1; *d*, maxilla 2; *e*, lower lip; *f*, gnathopod 1; *g*, gnathopod 2; *h*, peraeopod 2; *i*, peraeopod 3; *j*, uropod 3; *k*, telson.

slightly shorter than outer, each plate armed with four spines. Lower lip with suggestion of inner lobes; outer lobes narrowing distally, apex forming a small lobe below which is a depression carrying a short blunt spinule; lateral lobes rather prominent and apically blunt.

Gnathopods 1 and 2 very much alike. Gnathopod 1, fifth joint with lower lobe rather short, extending a very short distance along the hind margin of the sixth, bearing three apical spinules but no marginal setae or spinules; sixth joint broadest distally, palm transverse, defined by a small tooth and a spine, slightly convex and minutely denticulate throughout; seventh joint fitting palm, smooth on inner margin except for a tooth near the apex. Coxal plate 1 very little deeper than the first joint of the gnathopod and about half the depth of coxal plate 2, sides nearly parallel and lower corners evenly rounding. Gnathopod 2 larger than 1 but otherwise the same.

Peraeopods all very slender. Peraeopods 1 and 2 alike but 2 a little the longer; fourth joint with lower front angle produced; seventh joint rather long, slender and curved and bearing no nail or setae. Coxal plates 2, 3, and 4 of about equal depth. Peraeopod 3 longer than 2; depth of coxal plate equal to the length of the second joint. Peraeopod 4 longer than 3 but about equal in length to 5. The metasome segments are as figured by Sars (pl. 76, fig. 2) for *Gitanopsis bispinosa,* but without the dorsal teeth.

Uropod 1 reaching back as far as uropod 3, outer ramus scarcely shorter than inner. Uropod 2 reaching nearly to the middle of the rami of uropod 1, outer ramus considerably shorter than inner. Uropod 3, outer ramus shorter than inner, which is a little shorter than the peduncle. Telson reaching to about the middle of the peduncle of uropod 3, sides convex and converging to the narrow, evenly rounding apex. Length of female 3 mm.

Type locality.—Magdalena Bay, Lower California, dredged in 10-15 fathoms inside northern point of entrance to bay, July 14, 1938. Holotype, female, U.S.N.M. No. 79373.

Though many specimens of this species were taken, all appear to be females. *G. pusilloides* is probably most closely related to *G. pusilla* Barnard. There are, however, several distinguishing characters. The outer plate of maxilla 1 carries 7 spine teeth, while in *G. pusilla* there are 14. The inner plate of maxilla 2 is armed with 4 spine teeth, but in *G. pusilla* there are said to be 10 on apical and inner margins. The inner ramus of uropod 3 is about four-fifths the length of the peduncle. Barnard (1916, p. 144) says of *G. pusilla,* "Third uropod, outer ramus shorter than inner, which is a little shorter than peduncle," but in his figure of the third uropod the inner ramus is scarcely half the length of the peduncle, which proportion I suspect is correct.

COLOMASTIGIDAE

COLOMASTIX PUSILLA Grube

Colomastix pusilla Grube, 1864, Arch. Naturg., Jahrg. 30, vol. 1, p. 206, pl. 5, fig. 2 a-b.

Station 15. Sulivan Bay, James Island, Galápagos Islands, 1 specimen, ♀.

Station. Old Providence Island, Caribbean Sea, 1 specimen, ♀.

This is a widely distributed species and has been recorded from the Mediterranean, North Atlantic, Ceylon, South Africa, and Red Sea. The present records are the first for the Caribbean Sea and the Galápagos Islands.

BATEIDAE

BATEA CATHARINENSIS Müller

Batea catharinensis Müller, 1865, Ann. Mag. Nat. Hist., ser. 3, vol. 15, p. 276, pl. 10.

Batea secunda Holmes, 1905, Bull. Bur. Fish. for 1904, vol. 24, p. 499, fig.

Batea catharinensis Shoemaker, 1926, Proc. U. S. Nat. Mus., vol. 68, No. 2626, art. 25, p. 2, figs. 1-4.

Station 2. Cedros Island, off Lower California, 1 specimen, ♀.

Station 3. Magdalena Bay, Lower California, many specimens.

Station 4. Magdalena Bay, Lower California, 30 specimens.

This species extends from Brazil northward to southern New England. The present record is the first for the west coast of America.

GAMMARIDAE

MAERA SIMILE Stout

Maera simile Stout, 1913, Zool. Jahrb., Abt. Syst., vol. 34, p. 644.

Station 3. Magdalena Bay, Lower California, 2 specimens.

This species was described from specimens found in a large kelp holdfast which floated in to the breaker line from deep water at Laguna Beach, southern California.

The present record constitutes the second of the occurrence of this species.

ELASMOPUS RAPAX Costa

Elasmopus rapax Costa, 1853, Rend. Soc. Reale Barbonica, Acad. Sci., n. s., vol. 2, p. 175; Sars, 1895, Crustacea of Norway, Amphipoda, vol. 1, p. 521, pl. 183.

Station 3. Magdalena Bay, Lower California, 5 specimens.

Station 9. Clipperton Island, 2 specimens.

Station 15. Sulivan Bay, James Island, Galápagos Islands, 14 specimens.

Elasmopus rapax is a cosmopolitan inhabitant of the warm and temperate seas but has not heretofore been recorded from the west coast of America.

ELASMOPUS SPINIDACTYLUS Chevreux

Elasmopus spinidactylus CHEVREUX, 1907, Mem. Soc. Zool. France, vol. 20, No. 4, p. 486, figs. 9, 10.

Station 9. Clipperton Island, 15 specimens.

This species was described by Chevreux from the Gambier Islands, and has since been recorded from the Tuamotu and Gilbert Islands. The present record from Clipperton Island extends the range of this species greatly to the northeast.

ELASMOPUS BRASILIENSIS (Dana)

Gammarus brasiliensis DANA, 1853 and 1855, U. S. Explor. Exped., vol. 14, pt. 2, Amphipoda, p. 956, pl. 65, fig. 10.

Station. Old Providence Island, Caribbean Sea, 1 specimen.

Dana described this species from Rio de Janeiro, and there are specimens in the National Museum collection from the Gulf of Mexico and Florida. The present record is the first for the Caribbean Sea.

ELASMOPUS GRACILIS Schellenberg

Elasmopus gracilis SCHELLENBERG, 1938, Kungl. Svenska Vetensk. Akad. Handl., Tredje ser., vol. 16, No. 6, p. 59, fig. 31.

Station 9. Clipperton Island, 3 specimens, ♂.

This species was described from the Fiji Islands and Ellice Islands. The present specimens are about the size of the original specimens and they agree with the figures given by Schellenberg. This record from Clipperton Island is the second of the occurrence of this species.

TALITRIDAE

ORCHESTIA TRASKIANA Stimpson

Orchestia traskiana STIMPSON, 1857, Proc. California Acad. Nat. Sci., vol. 1, p. 90.

Station 1. Cedros Island, off Lower California, many specimens.

Station 3. Magdalena Bay, Lower California, 1 specimen, ♂.

This species is common on the west coast of the United States but has not heretofore been noted from Lower California.

ORCHESTIA MARQUESANA Stephensen

FIGURES 4, 5

Orchestia marquesana STEPHENSEN, 1935, B. P. Bishop Mus., Bull. 142, art. 3, p. 32, figs. 8-10.

Station 14. Clipperton Island, found among debris under two boobies' nests, July 21, 1938, many specimens.

Dr. Stephensen when describing this species had only the female, but both sexes occur in the specimens from Clipperton Island. I am therefore describing and figuring the male.

Male.—Eyes rather large, black. Antenna 1 reaching slightly beyond the end of the fourth joint of peduncle of antenna 2, flagellum slightly shorter than the peduncle. Antenna 2, flagellum much longer than peduncle. Mouth parts normal and as shown in the accompanying figures. Maxilla 1, inner plate with two plumose setae; outer plate with nine spine teeth. Maxillipeds, palp with small scalelike fourth joint which does not project beyond the apex of the third joint. Coxal plate 1 entirely hidden behind coxal plate 2, which is a little broader than deep and evenly rounding below. Coxal plates 4 and 5 of equal depth. Coxal plate 6 with deep hind lobe.

Gnathopod 1, fifth joint with a prominent hind lobe; sixth joint with the distal hind corner produced beyond the palm into a small lobe; palm transverse. Gnathopod 2, sixth joint robust; palm occupying nearly half the hind margin of joint and continuous with it; seventh joint a little longer than palm. Peraeopod 3 equal in length to peraeopod 2; second joint a little longer than wide and with a shallow lower hind lobe. Peraeopod 4, second joint considerably longer than wide and not greatly expanded. Peraeopod 5 equal in length to 4, second joint a very little longer than wide and having an almost square appearance, few serrations and spinules on hind margin.

Metasome segments 2 and 3 with lower hind corners slightly produced. The posterior lateral margins of metasome segments 1 to 3 bearing two or three shallow serrations. Pleopods with rami considerably reduced. Uropods 1 and 2 with rather few spines, the distal spines of uropod 1 being the longest. Uropod 3, ramus shorter than peduncle and bearing two small lateral spines and a group of spines apically; peduncle with three lateral spines. Telson a little longer than wide, cleft for about one-third its length with the lobes separated, a group of three lateral spines about one-third the distance from the end, two lateral spines near the apex, and two apical spines on each lobe. Length of largest specimens about 13 mm.

In the figure of the first gnathopod of the female given by Stephensen the palm appears to be slightly convex and slightly oblique. In the Clipperton Island specimens the palm is slightly concave, giving the

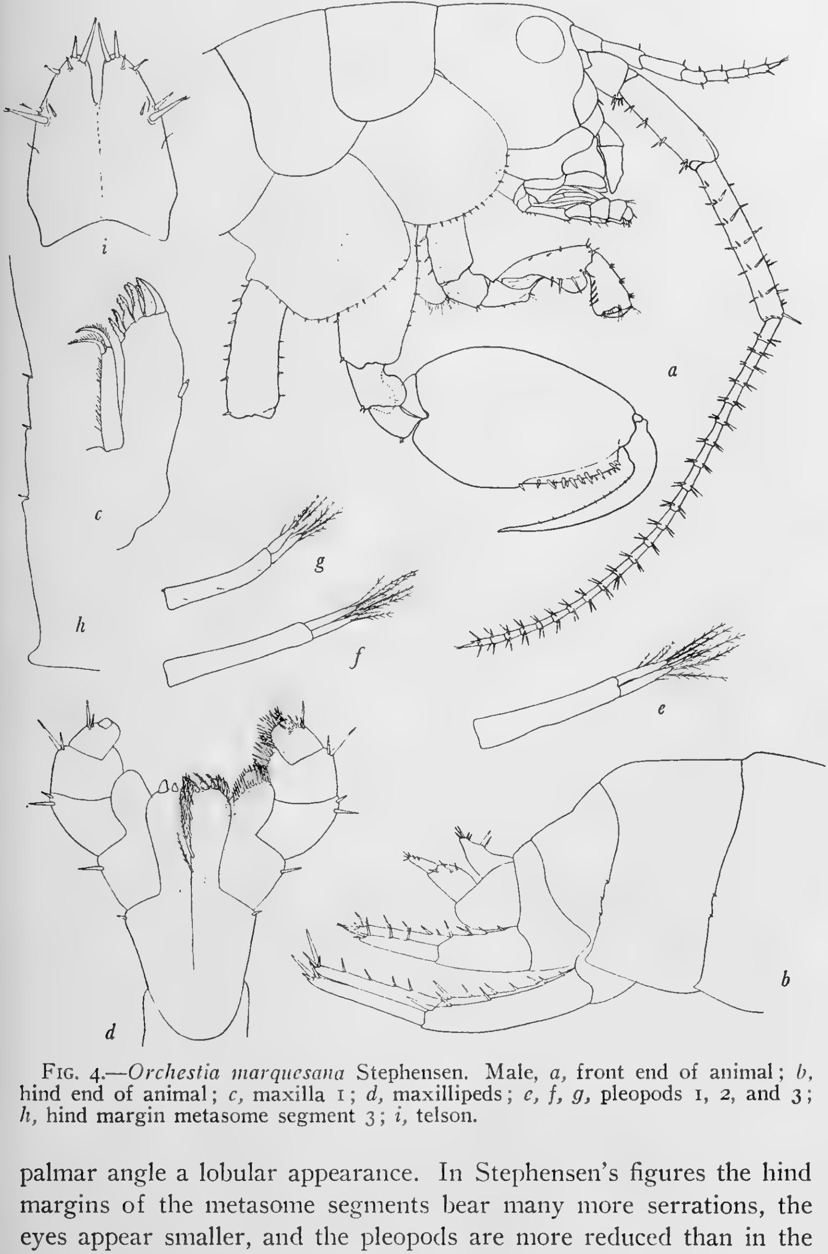

FIG. 4.—*Orchestia marquesana* Stephensen. Male, *a*, front end of animal; *b*, hind end of animal; *c*, maxilla 1; *d*, maxillipeds; *e*, *f*, *g*, pleopods 1, 2, and 3; *h*, hind margin metasome segment 3; *i*, telson.

palmar angle a lobular appearance. In Stephensen's figures the hind margins of the metasome segments bear many more serrations, the eyes appear smaller, and the pleopods are more reduced than in the

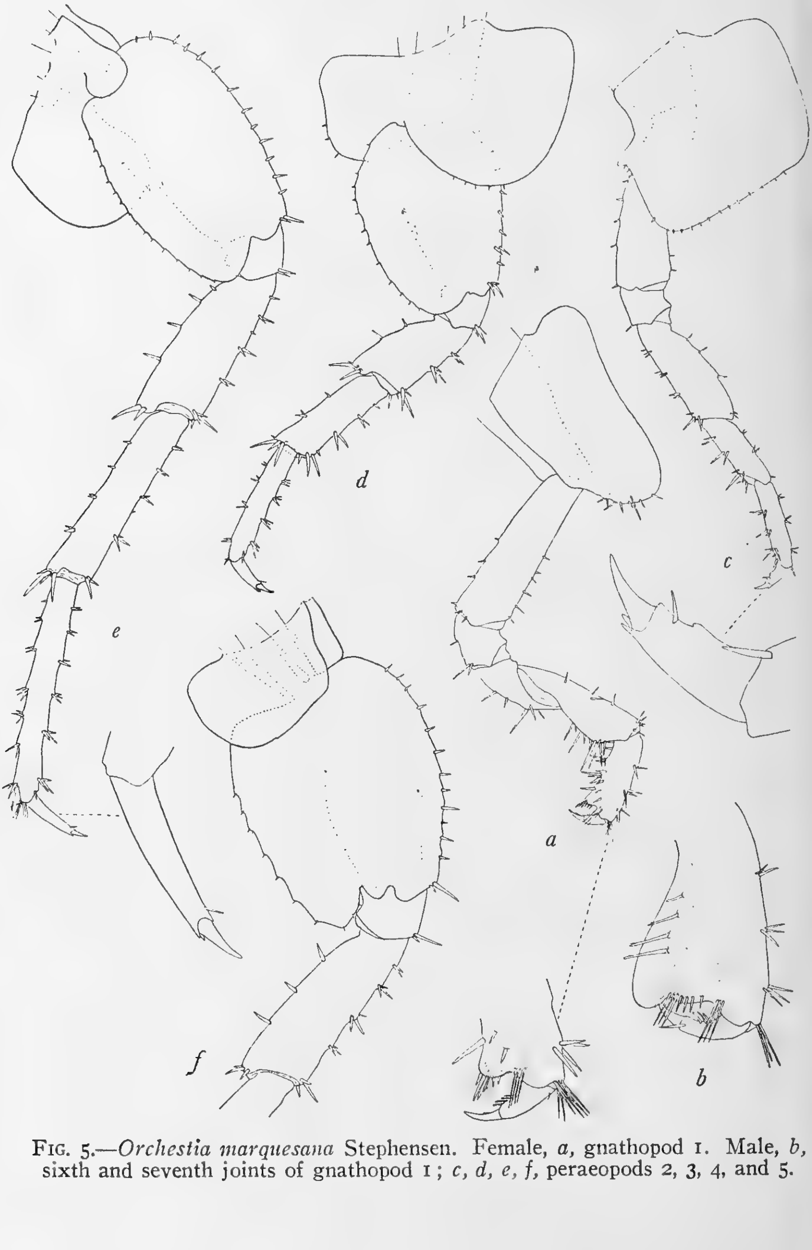

FIG. 5.—*Orchestia marquesana* Stephensen. Female, *a*, gnathopod 1. Male, *b*, sixth and seventh joints of gnathopod 1; *c, d, e, f*, peraeopods 2, 3, 4, and 5.

present specimens. I believe that in spite of these differences the Clipperton Island specimens belong to the species described from the Marquesas Islands and are *O. marquesana.*

These specimens were found in the debris under two boobies' nests, which were back from the beach well over 100 yards in a completely dry location, but the layer of debris in which the animals were found was moist.

The genera *Orchestia* and *Parorchestia* do not possess any characters by which they can be justly separated. Stebbing (1906, p. 530) says of *Orchestia,* "The maxillipeds seem sometimes to have an obscure rudiment of the fourth joint of the palp, and the front lobe of side-plate 5 may be as deep as side-plate 4." Of the genus *Parorchestia* he says (1906, p. 557), "Like *Orchestia,* but maxillipeds with fourth joint of palp distinct, though very small, conical, and having a spine on the truncate apex."

Chilton (1909, p. 636-637), after quoting Stebbing's definition of *Parorchestia,* says,

> In *Orchestia,* however, the maxillipeds may, as Stebbing himself states, have an obscure rudiment of the fourth joint of the palp, and the presence or absence of this joint is therefore hardly sufficient to distinguish the two genera. At the same time, it is perhaps convenient to group the truly terrestrial species under a separate genus, and the species that I am acquainted with can, as a rule, be distinguished from species of *Orchestia* living on the sea-shore by the greater abundance of long slender spine-like setae on the antennae and the peraeopods, and by the more reduced condition of the pleopoda, especially the third pair.

Dr. Stephensen (1935, p. 32), in describing *Orchestia marquesana,* places it in *Orchestia,* though he states that the palp of the maxillipeds has a minute, scalelike fourth joint. It would seem then that there are no characters sufficiently distinct to warrant the retention of the two genera, and I therefore regard *Parorchestia* as synonymous with *Orchestia.* The characters which have been used to distinguish the two genera differ only in degree, not in kind.

HYALE FREQUENS (Stout)

Allorchestes frequens Stout, 1913, Zool. Jahrb., Abt. Syst., vol. 34, p. 650.

Station 3. Magdalena Bay, Lower California ,15 specimens.

Station 4. Magdalena Bay, Lower California, 3 specimens.

Stout's specimens were taken at Laguna Beach, southern California, from tufts of coralline algae and from *Phyllospadix* between tides and also from tangles set below tides. The present specimens from Magdalena Bay were also found living among algae in 10-15 fathoms, and they constitute the second record of the occurrence of this species.

HYALE HAWAIENSIS (Dana)

Allorchestes hawaiensis DANA, 1853 and 1855, U. S. Explor. Exped., vol. 14, pt. 2, Amphipoda, p. 900, pl. 61, fig. 5.

Hyale brevipes CHEVREUX, 1901, Mem. Soc. Zool. France, vol. 14, p. 400, figs. 15-18; SHOEMAKER, 1933, Amer. Mus. Nov., No. 598, p. 18, figs. 10-11.

Hyale hawaiensis SCHELLENBERG, 1938, Kungl. Svenska Vetensk. Akad. Handl., Tredje ser., vol. 16, No. 6, p. 66, fig. 34.

Station 16. Narborough Island, Galápagos Islands, 6 specimens.

Dana described this species from the Hawaiian Islands, and it has been pointed out by Schellenberg that Chevreux's *Hyale brevipes* described from the Seychelles Islands is a synonym of it. *Hyale stolzmani,* described by Wrzesniowski from the coast of Peru, I believe is also a synonym of *H. hawaiensis. H. hawaiensis* is represented in the National Museum collection by specimens from Peru and the west coast of America as far north as California.

Hyale hawaiensis appears to be a cosmopolitan species in the warm and temperate seas.

AORIDAE

LEMBOS (BEMLOS) MACROMANUS (Shoemaker)

Bemlos macromanus SHOEMAKER, 1925, Bull. Amer. Mus. Nat. Hist., vol. 52, art. 2, p. 36, figs. 10-13.

Lembos (Bemlos) macromanus SCHELLENBERG, 1938, Kungl. Svenska. Vetensk. Akad. Handl., Tredje ser., vol. 16, No. 6, p. 79.

Station 3. Magdalena Bay, Lower California, numerous specimens.

Station 4. Magdalena Bay, Lower California, numerous specimens.

Station 5. Cape San Lucas, Lower California, 1 specimen.

This species was described from Lower California without a definite locality, but, as indicated by specimens recently presented to the National Museum, it appears to be a common species on the coast of that peninsula. The single male recorded by Schellenberg was from the Philippine Islands, which bespeaks a wide range for the species.

MICRODEUTOPUS SCHMITTI, new species [1]

FIGURE 6

Station 3. Magdalena Bay, Lower California, 11 specimens.

Station 4. Magdalena Bay, Lower California, 1 specimen.

Station 5. Cape San Lucas, Lower California, 1 specimen.

Male.—Head, side lobes rounding. Eye rather small, black, and composed of a few elements. Antenna 1 a little longer than 2, first

[1] Named in honor of Dr. Waldo L. Schmitt, the naturalist to the Presidential Cruise.

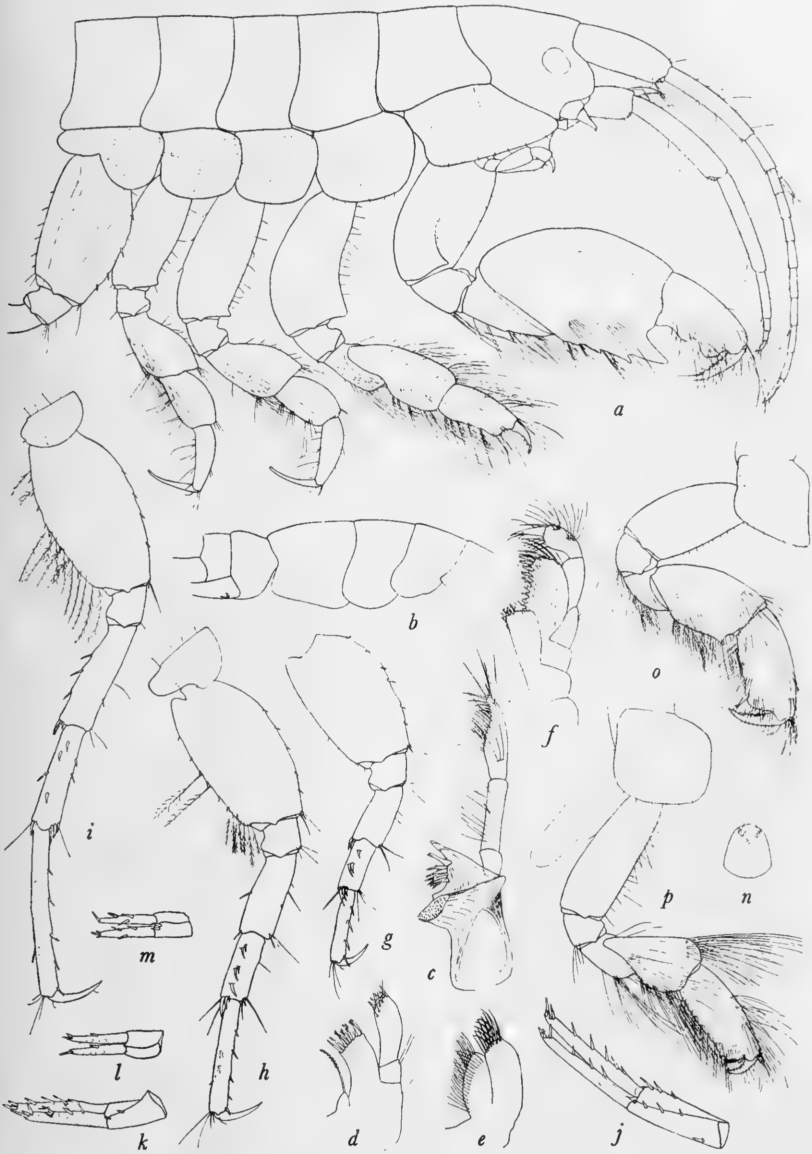

FIG. 6.—*Microdeutopus schmitti,* new species. Male, *a,* front end of animal; *b,* hind end of animal (on smaller scale than front end); *c,* mandible; *d,* maxilla 1; *e,* maxilla 2; *f,* maxilliped; *g,* peraeopod 3; *h,* peraeopod 4; *i,* peraeopod 5; *j,* uropod 1; *k,* uropod 2; *l, m,* uropod 3, from below and above; *n,* telson. Female, *o,* gnathopod 1; *p,* gnathopod 2.

and second peduncular joints about equal in length; third joint less than half the length of the second; flagellum about equal in length to the peduncle and composed of 9 or 10 joints; accessory flagellum consisting of 2 long and 1 very short joint. Several of the terminal flagellum joints carry long slender cylindrical sense organs. Antenna 2, fifth joint a little longer than fourth; flagellum about two-thirds the length of the fourth joint and composed of one long joint and three short joints, the three short joints each bearing a curved spine.

Mandible, molar prominent and bearing at its base near the insertion of the palp a prominent cone-shaped process; accessory plate narrow; six spines in spine row; second joint of palp shorter than third. Maxilla 1, inner plate small and bearing 1 long plumose seta; outer plate armed with 10 spine teeth; palp rounded distally and bearing 5 spine teeth and 4 setae. Maxilla 2, normal and much as figured by Sars for *M. anomalus* (pl. 191, fig. m^2), the diagonal row of setae on inner plate reaching nearly to the outer margin. Maxillipeds, inner plate bearing 3 teeth and the usual plumose setae; outer plate reaching nearly to the end of the second palp joint and armed on inner margin with 10 teeth; fourth joint of palp bearing nail at the base of which are several setules.

Gnathopod 1, strong and robust, second joint thick with the front margin excavate for the reception of the fifth joint when the limb is folded; fifth joint strongly developed with the hind margin produced distally into a forward-pointing tooth, back of which are two smaller teeth; sixth joint bearing two teeth on lower margin; seventh joint shorter than sixth, curved, with inner margin armed with five small teeth. Gnathopod 2, second joint strong, hind margin convex and the front margin concave; fifth joint longer and wider than sixth; sixth narrowing distally, palm transverse with evenly rounding defining angle and armed with exceedingly fine denticulations throughout; seventh joint overlapping palm and armed on inner margin with three small teeth; fourth, fifth, and sixth joints densely setose on their inner surfaces.

Peraeopods 1 and 2 very much alike, but 1 a little the stouter and longer; the lower inside surface of fourth joints densely clothed with long forward-pointing setae. Peraeopod 3 about equal in length to 2. Peraeopod 4 longer than 3, but shorter than 5. Coxal plate 1 produced forward to an evenly rounding, narrow, lower corner, lower margin nearly straight; coxal plate 2 deeper than 1 and deeper than the five following.

Metasome segments with lower hind corner narrowly rounding, segment 3 the longest. Uropod 1, peduncle about equal in length to outer ramus, which is a little shorter than inner; peduncle produced distally to a long upward-curved tooth. Uropod 2, peduncle shorter than outer ramus, which is shorter than the inner; peduncle produced distally into a long upward-curved tooth. Uropod 3 with outer ramus perhaps a little longer than inner. Telson reaching to end of peduncle of uropod 3, tumid, depressed along the central longitudinal dorsal surface, distal corners armed with three spinules and a seta, lateral margins slightly convex and converging toward the incised apex. Length of male 5 mm.

Female.—Much like the male except in gnathopods 1 and 2. Gnathopod 1, fifth joint as long as, but wider than, the sixth, lower front margin produced to a small tooth; sixth joint with front and hind margins about parallel, palm slightly oblique, defined by a broadly rounding curve at the base of which is a stout spine, palm minutely denticulate throughout; seventh joint overlapping palm and armed on inside margin with seven small teeth. The first coxal plate is neither so produced nor so long as in the male.

Gnathopod 2, fifth joint somewhat shorter, but much wider than sixth; sixth with front and hind margins about parallel, palm transverse, defined by an evenly rounding curve at the base of which is a stout spine, palm minutely denticulate throughout; seventh joint exactly fitting palm, and armed on inside margin with four small teeth. The second coxal plate is slightly deeper than the first and deeper than any of the following. Length of female 6 mm.

Type locality.—Magdalena Bay, Lower California, dredged in 10-15 fathoms inside northern point of entrance to bay, July 18, 1938. Holotype, male, U.S.N.M. No. 79375.

PHOTIDAE

PHOTIS SPINICARPA, new species

FIGURES 7, 8

Station 3. Magdalena Bay, Lower California, 16 specimens.

Male.—Head, lateral lobes moderately produced with front margin blunt and evenly rounding. Eye very small, round or slightly oval, black. Antenna 1 a little shorter than 2; flagellum consisting of about 10 joints. Antenna 2, flagellum consisting of from 12 to 14 joints. Mandible, molar strong and prominent; cutting edge toothed and very oblique; accessory plate simple, toothed; five spines in spine row, the two spines nearest molar being broadened and very much barbed apically; palp with third joint over half the length of second, apically rounding and bearing groups of spines on inner and outer surfaces in addition to the inner marginal spines; second joint bearing a few scattered spines on inner margin. Maxilla 1, inner plate reduced to a

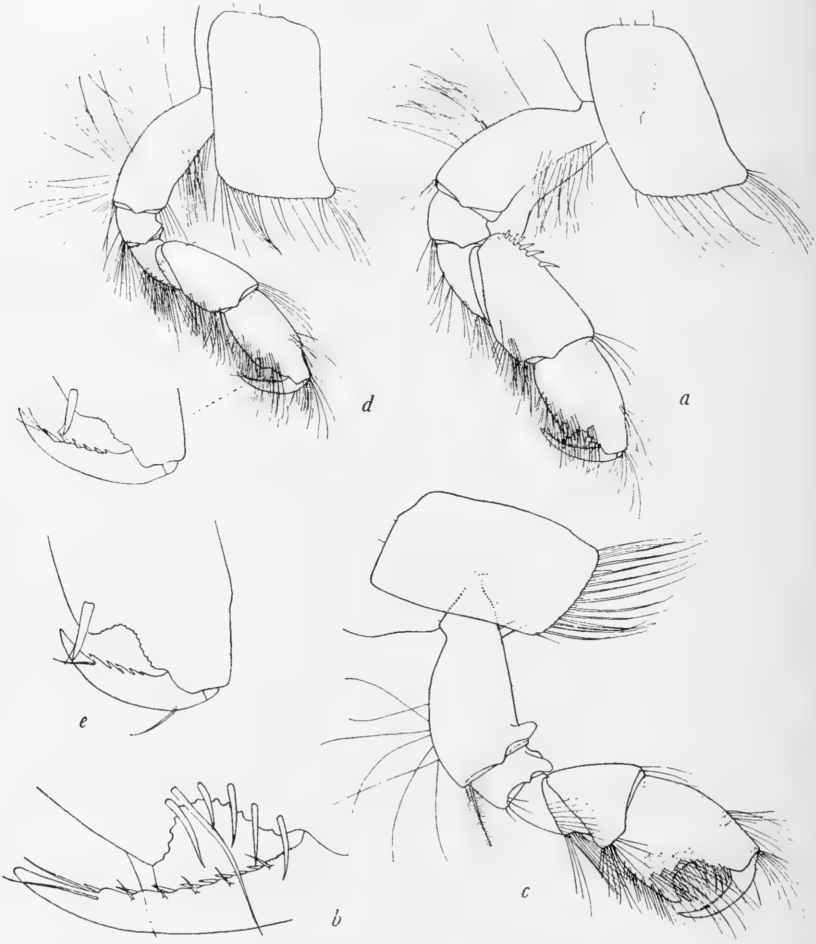

FIG. 7.—*Photis spinicarpa*, new species. Male, *a*, gnathopod 1; *b*, palm and seventh joint of gnathopod 1 greatly enlarged; *c*, gnathopod 2. Female, *d*, gnathopod 1; *e*, palm and seventh joint of gnathopod 2, greatly enlarged.

small conical lobe without setae; outer plate armed with 10 spine teeth; palp bearing on the obliquely truncate apex 6 spine teeth and 5 setae. Maxilla 2, outer plate wider and longer than inner; inner plate bearing, besides the inner marginal spines, a row of 25 closely set plumose setae which begins at the upper center of the plate and runs diagonally down to the lower inner edge. Maxillipeds, inner plate reaching to the middle of outer plate and bearing three teeth on upper margin;

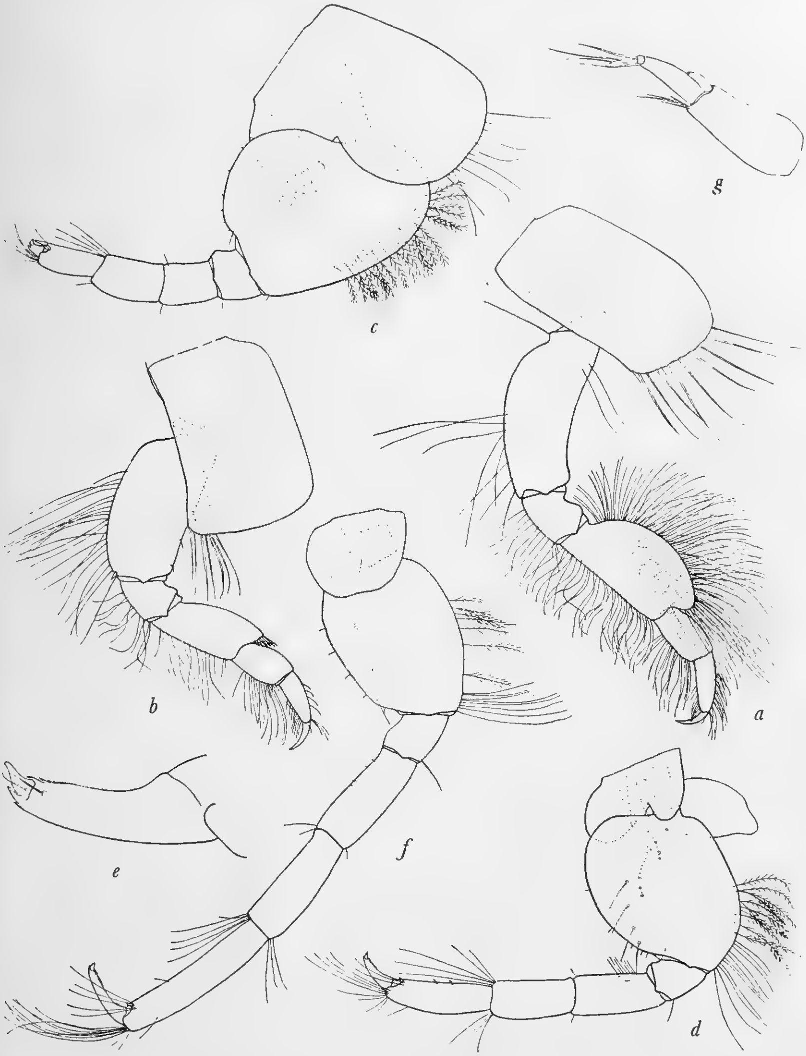

FIG. 8.—*Photis spinicarpa*, new species. Male, *a*, peraeopod 1; *b*, peraeopod 2; *c*, peraeopod 3; *d*, peraeopod 4; *e*, seventh joint of peraeopod 4 greatly enlarged; *f*, peraeopod 5; *g*, uropod 3.

outer plate reaching nearly to the end of second joint of palp and armed on upper inner margin and rounding distal margin with eight spine teeth and three curved pectinate spines; third joint of palp short and narrow; fourth joint rather small and bearing a prominent nail. Lower lip with lateral lobes rather small and slender; inner lobes very large.

Gnathopod 1, coxal plate somewhat produced forward, the lower front corner forming a slight lobe; second joint rather short and thick with lower front inner margin produced into a broadly rounding lobe; fifth joint shorter than second and slightly longer than sixth and armed on upper proximal margin with a row of short stout spines; sixth joint narrowing distally, palm very oblique, concave, defined by a prominent angle on the inside of which is a stout spine, and crenulate throughout; seventh joint curved, bearing a row of fine teeth on inner margin and considerably overlapping palm.

Gnathopod 2, second joint short and stout and bearing at the lower front corner a narrow lobe which stands at a right angle to the joint; third joint bearing a narrow, downward-pointing lobe on front margin; fifth joint about two-thirds the length of sixth; sixth joint broadly oval and only a little longer than wide, palm oblique, deeply convex, crenulate throughout, and forming a produced angle with the hind margin, the produced angle bearing a stout spine on inner surface; seventh joint curved, bearing a row of fine teeth on inner margin and somewhat overlapping palm.

Peraeopod 1 longer and stouter than 2; second joint as long as third and fourth together; fourth joint considerably expanded and clothed with a dense armament of long plumose setae. Peraeopod 2 as shown in figure 8, *b*. Peraeopod 3, coxal plate slightly deeper than that of peraeopod 2; limb short and curved up over back of animal; second joint very much expanded. Peraeopod 4, second joint not as greatly expanded as in 3; limb curved backward from the third joint; seventh joint stout, armed on inner margin with a row of fine teeth becoming coarser as they approach the nail which bears several barbs on its outer base. Peraeopod 5 conspicuously longer than 4; second joint less expanded than that of 4; seventh joint long and prominent with armature similar to that of 4.

Uropod 1 extending back a little farther than 2. Uropod 3 extending back as far as 2 or perhaps a little farther. Uropod 3, longer ramus about two-thirds the length of peduncle, second joint cylindrical and very short and armed with a long spine and several long setae; shorter ramus a little over one-third the length of the longer and bearing a very small apical spinule. Telson broadly triangular. Length of male 7 mm.

Female.—The female is very much like the male in general appearance. The gnathopods are not so strong and robust as in the male.

Palm of the first gnathopod very oblique, slightly concave, and defined by a low, evenly rounding angle bearing a prominent spine; seventh joint armed on inside margin with a row of fine teeth, and considerably overlapping palm. Gnathopod 2, palm more concave than in gnathopod 1, but not as deeply concave as that of male; seventh joint armed on inner margin with strong serrations and somewhat overlapping palm. Length 7 mm.

Type locality.—Magdalena Bay, Lower California, dredged in 10-15 fathoms inside northern point of entrance to bay, July 18, 1938. Holotype, male, U.S.N.M. No. 80028.

PHOTIS BREVIPES, new species

FIGURE 9

Station 3. Magdalena Bay, Lower California, 30 specimens.

Station 4. Magdalena Bay, Lower California, 1 specimen.

Male.—Head with lateral lobes very little produced. Eyes small, oval, black. Antenna 1 about equal in length to antenna 2, flagellum 6-jointed. Antenna 2, flagellum 6-jointed. Coxal plates 1 to 5 deeper than their segments; 1 and 2 not as deep as 3, 4, or 5 which are about equal in depth.

Gnathopods 1 and 2 short and stout. Gnathopod 1, second joint bearing a slightly produced lower front lobe; fifth joint shorter but equal in width to sixth; sixth joint, palm oblique and rather deeply excavate with a low protuberance near the seventh joint, defined by a prominent angle, submarginal to which is a prominent spine on the inner surface of the joint; the palm is very finely crenulate throughout; seventh joint armed distally on the inner margin with three forward-pointing spine teeth and proximally with a row of very fine, closely set teeth. Gnathopod 2 a little longer and much stouter than 1, second joint bearing a rather prominent lower front lobe; fifth joint short and narrowly produced between fourth and sixth; sixth joint nearly as wide as long, palm nearly transverse, deeply incised, forming a prominent defining tooth, and bearing a triangular tooth near the seventh joint; seventh joint short and stout and bearing a rounding protuberance near the center of the inner margin.

Peraeopod 1 very little longer than 2, second joint a little longer than third and fourth combined; fourth joint slightly expanded distally with lower front margin a little produced; fifth and sixth joints short and, combined, equal in length to the fourth. The third, fourth, and fifth joints bearing plumose setae on the hind margin; and the

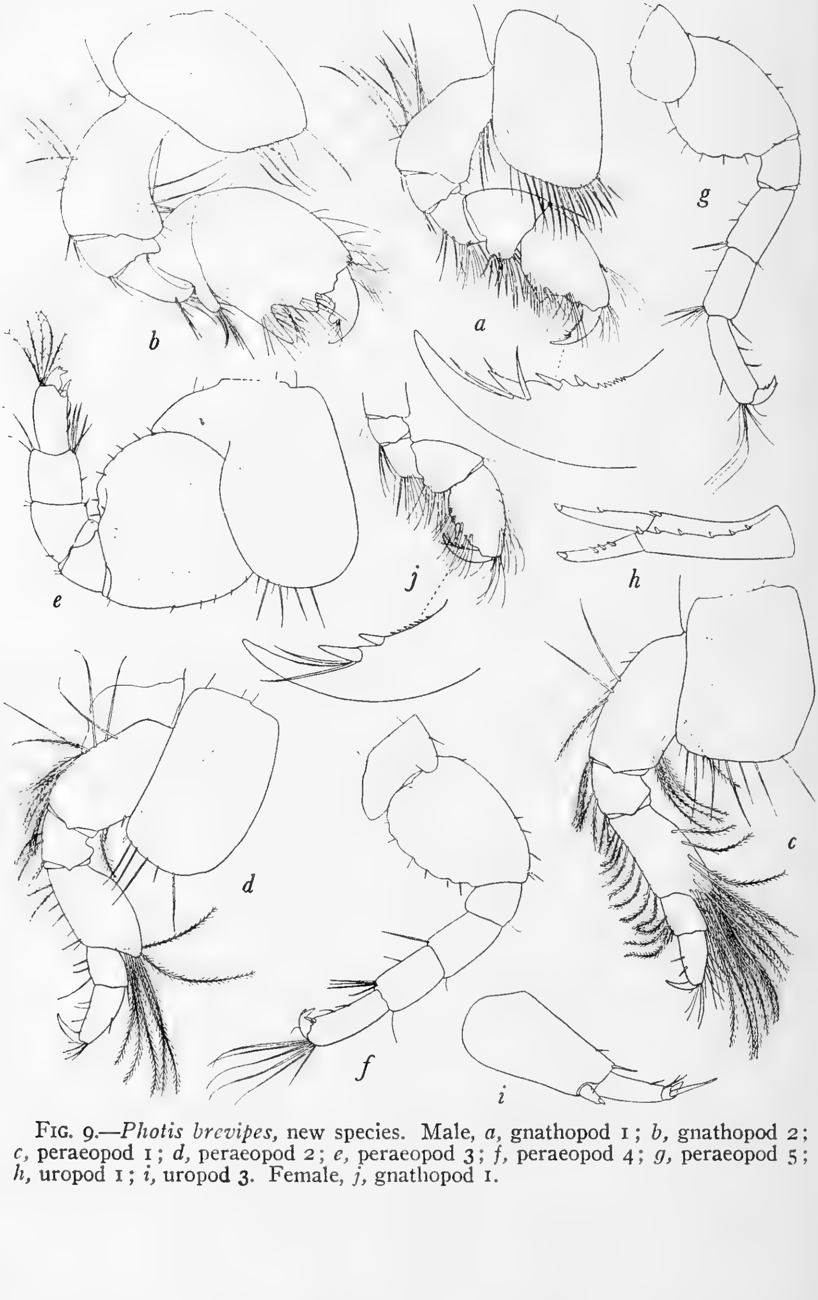

FIG. 9.—*Photis brevipes,* new species. Male, *a,* gnathopod 1; *b,* gnathopod 2; *c,* peraeopod 1; *d,* peraeopod 2; *e,* peraeopod 3; *f,* peraeopod 4; *g,* peraeopod 5; *h,* uropod 1; *i,* uropod 3. Female, *j,* gnathopod 1.

fourth joint bearing plumose setae on the front and lower margins, those of the lower margin being very long and extending much beyond the sixth joint. Peraeopod 2 in general much like peraeopod 1, but does not bear so many plumose setae. Peraeopod 3 short and assuming the usual upward-pointing position characteristic of the genus *Photis;* the second joint is nearly circular, being as wide as long; the three following joints are very short and wide; the sixth joint is narrower, being twice as long as wide; the seventh joint is short with the bent apex and two small outer teeth found in this genus. Peraeopods 4 and 5 are about equal in length and are a little longer than 3. Peraeopod 4 assumes much the same position as peraeopod 3, though not pointing so sharply upward; the seventh joint is much like that of 3 and when closed against the end of the sixth joint forms a decided hook. Peraeopod 5 has the appearance and structure normal to the great majority of the Gammaridea as shown in figure 9, *g*.

Uropods 1 and 2 extending back about the same distance; uropod 3 extending back not quite so far as 2. Outer ramus of uropod 1 bears three spines on upper margin, while the inner ramus bears only one; the outer edge of the peduncle bears six spines, and the inner edge bears only one terminal spine. Outer ramus of uropod 2 bears two spines on upper margin and the inner ramus bears three; the peduncle bears two spines on outer edge and one terminal spine on inner edge. Telson normal and reaching to the middle of the peduncle of uropod 2. Length about 3 mm.

Female.—The female appears somewhat more robust than the male, but differs principally in the gnathopods. The palm of gnathopod 1 is very oblique and merges imperceptibly into the hind margin of the joint by an evenly rounding curve, but is defined by a stout spine; the palm is armed throughout with very fine, sharp, closely set teeth; the seventh joint is much like that of the male, but the inner margin bears two teeth instead of the three possessed by the male. Gnathopod 2 closely resembles gnathopod 1 of the male; the crenulate palm and the seventh joint like those of gnathopod 1 of the male, but the fifth joint is narrowly produced between the fourth and sixth as it is in gnathopod 2 of the male. Length about that of the male or a very little longer.

Type locality.—Magdalena Bay, Lower California, dredged in 10-15 fathoms inside northern point of entrance to bay, July 18, 1938. Holotype, male, U.S.N.M. No. 79360.

EURYSTHEUS TENUICORNIS (Holmes)

FIGURE 10, *d, e*

Gammaropsis tenuicornis HOLMES, 1904, Harriman Alaska Exped., p. 239, fig. 124.

Eurystheus tenuicornis SHOEMAKER, 1931, Proc. U.S. Nat. Mus., vol. 78, No. 2861, art. 18, p. 5, figs. 3, 4.

Station 3. Magdalena Bay, Lower California, 1 specimen.

Station 4. Magdalena Bay, Lower California, 2 specimens.

This species was described by Holmes from Puget Sound, Wash., from a single male specimen which did not possess fully developed characters. *E. tenuicornis* inhabits the entire west coast of the United States and Lower California and was taken by the *Albatross* in the Gulf of California.

EURYSTHEUS TENUICORNIS var. LOBATA, new variety

FIGURE 10, *a-c*

Station 3. Magdalena Bay, Lower California, 25 specimens.

Station 4. Magdalena Bay, Lower California, 1 specimen.

Male.—This variety is distinguished by the enlargement of the second joint of the first gnathopod and by its downward production into a broadly rounding lobe which is furnished with a dense brush of long forward-curving simple setae. The broadly triangular central dorsal tooth of the first urosome segment is produced upward and is curved forward toward the metasome. Length 8.5 mm.

The female does not differ materially from that of *Eurystheus tenuicornis.*

Type locality.—Magdalena Bay, Lower California, dredged in 10-15 fathoms inside northern point of entrance to bay, July 18, 1938. Holotype, male, U.S.N.M. No. 79376.

There are specimens of this variety in the National Museum collection from the following localities: *Albatross* station 2835, off Lower California, 26°42′30″ N., 113°34′15″ W., May 4, 1888, 5.5 fathoms, 3 specimens; San Diego, Calif., 10 fathoms, collected by Henry Hemphill in 1882, 8 specimens; La Jolla, Calif., from kelp holdfast washed up on beach after storm, March 4, 1938, collected by Olga Hartman, 8 specimens; Newport Bay, Calif., collected by G. E. MacGinitie from seaweed on rocks, December 29, 1932, many specimens; same locality, from among hydroids, etc., July 14, 1935, 4 specimens.

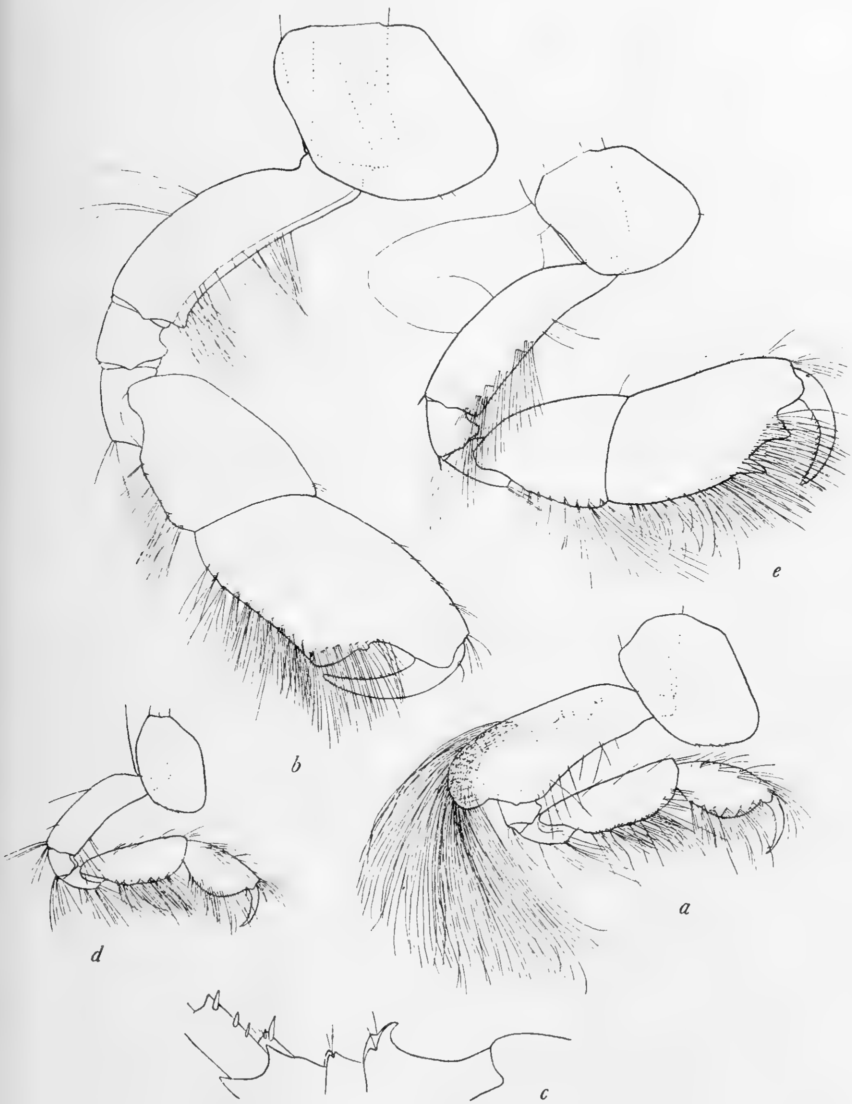

FIG. 10.—*Eurystheus tenuicornis* var. *lobata*, new variety. Male, *a*, gnathopod 1; *b*, gnathopod 2; *c*, urosome. *Eurystheus tenuicornis* Holmes; *d*, gnathopod 1; *e*, gnathopod 2.

EURYSTHEUS SPINOSUS, new species

Figure 11

Station 3. Magdalena Bay, Lower California, 11 specimens.

Male.—Head with lateral lobes produced and rather sharply angular; eyes small, oval, and black. Antennae nearly equal in length, antenna 2 being perhaps a little the longer. Antenna 1, third joint of peduncle equal in length to the first, but shorter than second, flagellum not as long as second and third peduncular joints combined, and composed of six joints; accessory flagellum 3-jointed. Antenna 2, fourth and fifth joints equal in length, flagellum a little longer than fifth peduncular joint, and composed of five joints.

Mandibles with molar well developed. Right mandible with accessory plate bifurcate and toothed; three spines in spine row; third joint of palp shorter than second and distally truncate. Maxilla 1, inner plate triangular with acute apex and without setae; outer plate armed with 10 spine teeth; palp bearing distally 5 spine teeth and 4 setae. Maxilla 2, inner plate as wide as, but slightly shorter than, outer, distally broadly and evenly rounding, and bearing an oblique row of closely set setae near inner margin. Maxillipeds, inner plate not quite reaching the middle of outer plate, armed distally with three spine teeth, and bearing a spine tooth on inner margin near the upper angle; outer plate reaching a little beyond the middle of the second joint of the palp, inner margin armed with seven spine teeth, two of which are placed on the upper rounding angle; palp 4-jointed, the last joint being small, obliquely truncate and bearing distally three spines. Lower lip with inner lobes very prominent, and lateral processes very acute.

Gnathopod 1, second joint longer than fifth, fifth a little longer than sixth; sixth narrowing distally, palm defined by a slight angle and a spine, and bearing a low tooth near the hinge of the seventh joint; seventh joint longer than palm and armed on inner margin with a few minute teeth. Gnathopod 2, fifth joint as wide as, but shorter than, sixth; sixth joint with front and hind margins about parallel, palm oblique and equal in length to hind margin, bearing two low teeth and defined by a small tooth.

Peraeopods 1 and 2 alike, but 1 a little the longer. Peraeopod 3, coxal plate very large and as deep as the fourth; second joint greatly developed, being as wide as long; fourth joint considerably expanded, hind margin convex and bearing a conspicuous row of stout spines. Peraeopod 4 about as long as 3 but longer than peraeopod 5. Peraeopods 3 to 5 all strongly curved and extending up over the back.

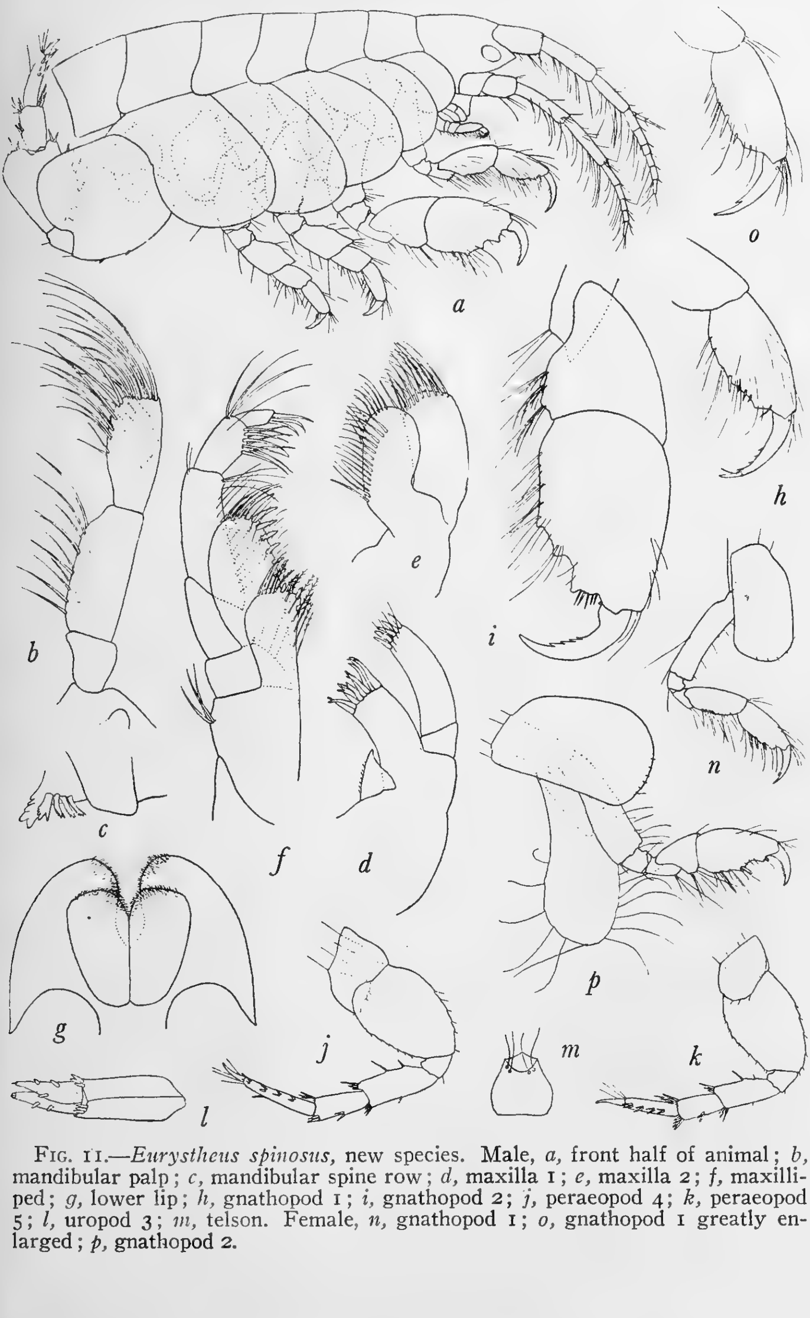

FIG. 11.—*Eurystheus spinosus*, new species. Male, *a*, front half of animal; *b*, mandibular palp; *c*, mandibular spine row; *d*, maxilla 1; *e*, maxilla 2; *f*, maxilliped; *g*, lower lip; *h*, gnathopod 1; *i*, gnathopod 2; *j*, peraeopod 4; *k*, peraeopod 5; *l*, uropod 3; *m*, telson. Female, *n*, gnathopod 1; *o*, gnathopod 1 greatly enlarged; *p*, gnathopod 2.

Metasome segments with lower posterior corners broadly rounding with the indication of a very slight and broad posterior angle in the second. Uropod 2 reaching a little farther back than 1, but not as far as uropod 3. Uropods 1 and 2, inner ramus longer than outer. Peduncle of uropod 1 produced distally into an upward-curved tooth. Uropod 2 is without the peduncular tooth. Telson reaching to about the middle of the peduncle of uropod 3, about as broad as long, narrowing distally, slightly emarginate above and bearing two setules on either side of the center of the emargination. Length of mature male about 3 mm.

Female.—The female differs from the male principally in the second gnathopod and the third peraeopod. The palm is very oblique, has a single palmar tooth near the hinge of the seventh joint, and is defined by a right angle and a spine. Peraeopod 3 is not so robust as in the male, the second joint is not so much expanded, the fourth joint is little expanded and lacks the characteristic row of spines of the male, and the fifth and sixth joints are proportionately longer. Length about 3 mm.

Type locality.—Magdalena Bay, Lower California, dredged in 10-15 fathoms inside northern point of entrance to bay, July 18, 1938. Holotype, male, U.S.N.M. No. 79377.

PODOCEROPSIS DUBIA, new species

FIGURE 12

Station 28. Chatham Bay, Cocos Island, 23 specimens.

Male.—Head about as long as first two body segments; lateral lobes produced but not acutely so; lower margin deeply incised for the insertion of antenna 2; eye rather large and placed on the lateral lobe. Antenna 1 shorter than 2, third peduncular joint longer than first and about two-thirds the length of the second; flagellum about as long as the second and third peduncular joints combined and composed of about 10 joints, the last 5 or 6 of which bear long, slender sensory organs. Antenna 2, third peduncular joint unusually elongate, fourth very little shorter than fifth; flagellum very nearly as long as the peduncle and composed of about 14 joints.

Mouth parts very nearly as figured by Sars for *Megamphopus cornutus* (pl. 200). Upper lip with lower margin evenly rounding. Mandible, molar prominent with the base near the insertion of the palp produced into a blunt rounding knob; accessory plate present on both right and left mandible; eight or nine spines in spine row; third joint of palp shorter than second. Maxilla 1, inner plate rather

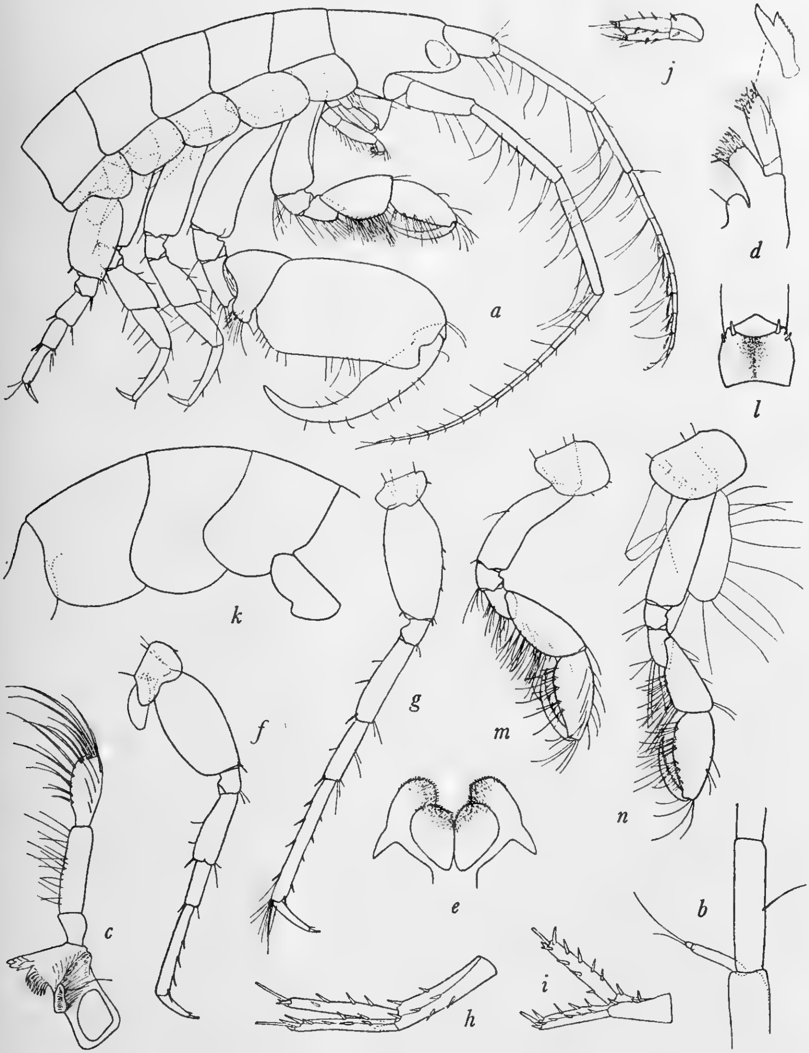

FIG. 12.—*Podoceropsis dubia,* new species. Male, *a,* front half of animal; *b,* antenna 1; *c,* mandible; *d,* maxilla 1; *e,* lower lip; *f,* peraeopod 4; *g,* peraeopod 5; *h,* uropod 1; *i,* uropod 2; *j,* uropod 3; *k,* metasome, on larger scale than front half of animal; *l,* telson. Female, *m,* gnathopod 1; *n,* gnathopod 2.

small, evenly rounding distally and bearing a single seta; outer plate armed with 10 spine teeth; palp armed distally with 2 simple spines between which are 3 serrate spine teeth. Lower lip with lateral lobes rather short and angular. Coxal plates all rather shallow; coxal plate 1 produced forward very slightly; coxal plate 2 the deepest, but little deeper than 1; coxal plates 3 and 4 successively shallower, 4 not as deep as 5.

Gnathopod 1, fifth joint as long as sixth, but wider; sixth rather narrow and converging distally, palm very long, without defining spine and not differentiated from short hind margin; seventh joint nearly as long as sixth and bearing a few setules on inner margin. Gnathopod 2 large and robust, fifth joint short, about one-third the length of sixth and produced behind into a small lobe; sixth joint strongly developed, front and hind margins about parallel, hind margin produced distally into a low rounding lobe, palm not defined; seventh joint stout, strongly curved distally and about equal in length to the hind margin of the sixth joint. The seventh joint does not appear to close against the sixth joint, but normally remains gaping as shown in figure 12, *a*.

Peraeopods 1 and 2 alike in structure, but 1 a little the larger; seventh joints rather short and glandular. Peraeopod 3 shorter than 2, second joint not much expanded. Peraeopod 4 longer than 3, but shorter than 5; second joint of 4 and 5 not much expanded, and their seventh joints much longer than in the preceding peraeopods.

Metasome segments much as figured by Sars for *M. cornutus* (pl. 200), all having their lower hind corners broadly rounding, and segment 3 being the longest. Uropod 1 projecting farther back than 2, which projects farther back than 3. Uropod 1, peduncle produced distally below into an upward-curving tooth, outer ramus a little shorter than inner. Uropod 2 without the peduncular tooth, outer ramus shorter than inner. Telson wider than long, reaching to about one-third the distance along the rami of uropod 3, sides convex, each distal corner bearing two short spinules and a long seta, and dorsal surface bearing a longitudinal depression. Length of male about 3 mm.

Female.—The female differs from the male only in the gnathopods. Gnathopod 1 is proportionately longer and slenderer; the fifth and sixth joints are equal in length and are longer and not as wide as in the male. Gnathopod 2 is much like gnathopod 1 of the male, the slight differences being shown by the figures. The palms of both gnathopods are without defining spines and are not differentiated from the hind margin of the joints. Length, female, 3 to 3.5 mm.

Type locality.—Chatham Bay, Cocos Island, taken in a bottom sample, mostly sand, August 3, 1938. Holotype, male, U.S.N.M. No. 79378.

Remarks.—This is an aberrant species and does not fit into any of the genera of the Photidae as characterized by Stebbing. It is nearest to *Podoceropsis* and *Megamphopus.* These two genera differ from each other in the relative length of the fifth and sixth joints of the second gnathopod of the male, being short in *Podoceropsis* and long in *Megamphopus.* In the present species the fifth joint is short in the male, but the sixth joint of gnathopod 2 in the female is not conspicuously wider than that of gnathopod 1, a character of *Podoceropsis* given by Stebbing. Gnathopods 1 and 2 of the female are much like those figured by Sars for *Megamphopus cornutus* (pl. 200). The very small accessory flagellum is like that of *Megamphopus.* The second coxal plate is the largest in both male and female, agreeing with *Megamphopus.* The mouth parts could be claimed by either *Podoceropsis* or *Megamphopus.* The mandible closely resembles that figured by Sars for *M. cornutus* (pl. 200). The inner plate of maxilla 1 is not obliquely truncate with the single seta at the apex of the somewhat produced corner as shown by Sars for *M. cornutus* (pl. 200) or *Podoceropsis excavata* (pl. 205), but is broadly and evenly rounding with the seta at the opposite corner from that shown by Sars.

In many characters *Podoceropsis dubia* bears a striking resemblance to *Megamphopus longidactylus* Chevreux (1925, p. 388), which is also an aberrant species and does not conform to either *Megamphopus* or *Podoceropsis.* The present species differs from *M. longidactylus* by having gnathopod 1 of the male much more robust, and the metacarpus of gnathopod 2 much wider than the carpus.

NEOMEGAMPHOPUS, new genus

Body slender. Head with lateral lobes considerably projecting. Eyes well developed. Antennae 1 and 2 slender and 1 the shorter. Acessory flagellum very small, 2-jointed. Mandibular palp stout, third joint shorter than second and distally truncate. Maxilla 1, inner plate with 1 or 2 setae; outer plate with 10 spine teeth. Maxilla 2, outer plate broader and longer than inner, inner plate bearing oblique row of spinules. Maxillipeds, inner plate shorter than outer and bearing two teeth on truncate extremity; outer plate bearing a few teeth on inner edge and a few plumose spines and a few spine teeth on upper margin. Lower lip with very well-developed inner lobe. Gnathopod 1 in male the larger; fifth joint greatly developed with lower margin produced forward into a tooth; sixth and seventh joints slender. Gnathopod 2 in male long and slender; sixth joint shorter than fifth and bearing the mere suggestion of a palm. Gnathopods 1 and 2 in female simple and much like gnathopod 2 of male. Side plate 4 not excavate behind. All peraeopods with second joint about equally expanded. Peraeopod 5 the longest. All uropods with outer ramus shorter than inner. Outer ramus of uropod 3 apparently with a very small indistinct second joint. Telson simple, tumid. Genotype, *Neomegamphopus roosevelti.*

NEOMEGAMPHOPUS ROOSEVELTI, new species [2]

FIGURE 13

Station 3. Magdalena Bay, Lower California, many specimens.
Station 4. Magdalena Bay, Lower California, many specimens.
Station 5. Cape San Lucas, Lower California, 6 specimens.

Male.—Head about as long as the first two body segments; lateral lobes strongly produced and bearing the rather large oblique eye. Lower part of head cut far back for the insertion of antenna 2. Antenna 1, second joint longest; third a little shorter than first; flagellum about as long as second and third joints combined and composed of about 10 joints; accessory flagellum shorter than first joint of primary flagellum and composed of 1 long and 1 very short joint. Antenna 2 with third, fourth, and fifth joints increasing consecutively in length; flagellum not as long as fourth and fifth joints combined and composed of about 10 joints.

Mandibles with prominent molar; cutting edge rather narrow and toothed; accessory plate well developed and toothed; six serrate spines in spine row; palp stout with spines on upper and lower margins of second joint, and many long spines on extremity of third joint. Maxilla 1, inner plate obliquely truncate and bearing 1 or 2 simple setae; outer plate armed with 10 serrate spine teeth; palp with first joint short, second joint broad and long, and armed distally with several jagged, serrate teeth and five setules. Maxilla 2, outer plate much broader than inner; inner plate with spinules along the entire inner edge and an oblique row near inner edge. Maxillipeds, inner plate with two teeth at inner corner of truncate distal margin, and an oblique row of plumose setae on inner surface; outer plate reaching to about two-thirds the length of the second palp joint, inner

[2] I take great pleasure in naming this species for the Hon. Franklin D. Roosevelt, President of the United States of America, in appreciation of his interest in the biological collections of the U. S. National Museum.

margin armed with four spine teeth and the upper margin with two plumose spines and two slender spine teeth; second joint of palp slender and longer than the third and fourth combined, fourth joint

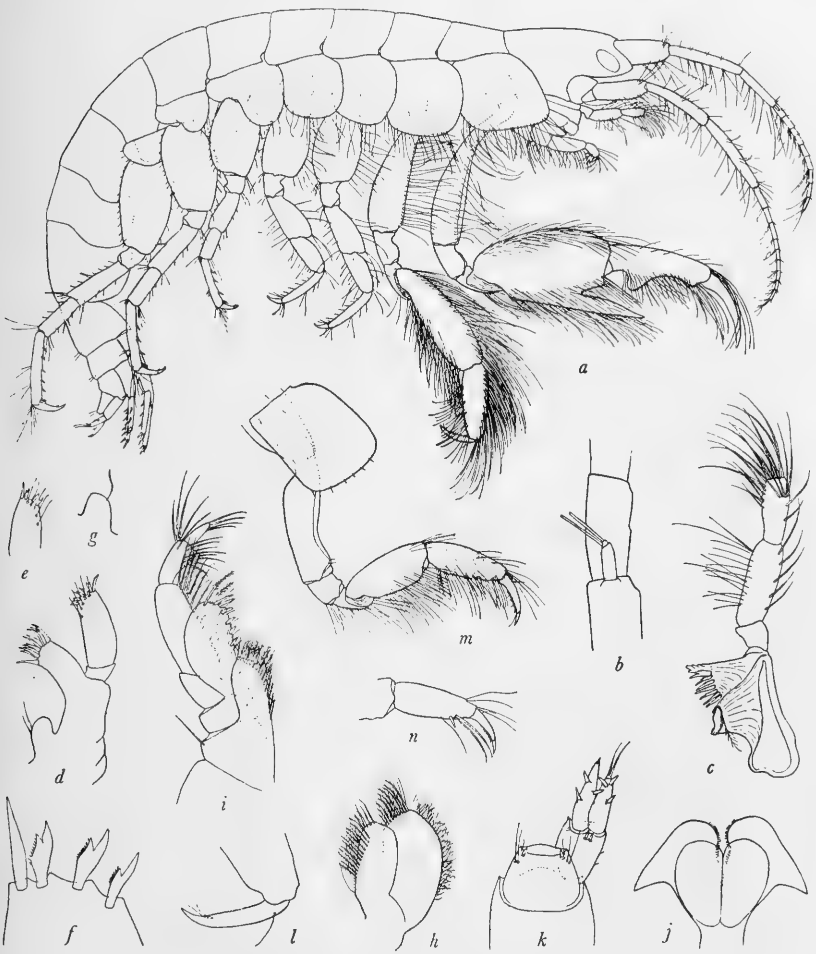

FIG. 13.—*Neomegamphopus roosevelti*, new species. Male, *a*, entire animal; *b*, accessory flagellum of antenna 1; *c*, mandible; *d*, maxilla 1; *e*, palp of left maxilla 1; *f*, end of palp of maxilla 1, enlarged; *g*, inner plate of left maxilla 1; *h*, maxilla 2; *i*, maxilliped; *j*, lower lip; *k*, telson and uropod 3; *l*, end of gnathopod 2, enlarged. Female, *m*, gnathopod 1; *n*, end of gnathopod 2.

without nail, but bearing four spinules at apex. Lower lip with very large, well-developed lobes and rather short, wide side lobes.

Coxal plates 1 and 2 larger than the rest, 3, 4, and 5 of equal depth, and 6 and 7 shallowest. Gnathopod 1 large and strong; first joint long and slender; fifth joint with lower margin produced forward into a single pointed tooth above which is a narrow sinus; sixth joint much slenderer than fifth and bearing a prominent tooth near the proximal end; seventh joint curved and about two-thirds the length of the sixth. Fifth and sixth joints very hirsute. Gnathopod 2 slender and much longer than the peraeopods; fifth joint about as wide and as long as the second; sixth joint narrower than, and about two-thirds the length of, the fifth, with a very inconspicuous palm; seventh joint slender, slightly curved, bearing very fine serrations on inner margin and a small spine and two setae near the apex.

Peraeopod 1 somewhat longer than 2, the second joint much expanded. Peraeopod 3 shorter than 2. Peraeopod 4 longer than 3. Metasome segments 1 to 3 with the lower posterior corner broadly rounding. Urosome segments 1 and 2 each bearing two dorsal setae. Uropods all reaching back about the same distance. Peduncle of uropod 1 produced distally to a strong tooth. Uropod 3, outer ramus about as long as the peduncle. Telson tumid, a little wider than long, slightly indented when viewed directly from above, and bearing a small spine and two setae at either distal corner. Length of fully developed males 4.5 to 5 mm. from front of head to end of uropod 3. Females slightly smaller.

Female.—The female differs from the male only in the gnathopods and the first two coxal plates. The first two coxal plates are not larger or deeper than the three following. Gnathopods 1 and 2 are much like gnathopod 2 of the male, but the fifth joint is proportionately shorter. In gnathopod 2 the palm is even less conspicuous than in the male.

Type locality.—Magdalena Bay, Lower California, from filamentous green algae inside northern point of entrance to bay, 15 fathoms, sandy, weedy bottom, July 18, 1938. Holotype, male, U.S.N.M. No. 79298.

Remarks.—This genus cannot properly be assigned to any of the families as characterized by Stebbing in "Das Tierreich." It is a combination of the characters of the families Aoridae and Photidae. The large first gnathopod of the male closely resembles that of *Microdeutopus,* but the antennae, mouth parts, and head generally, are much more closely allied to those of *Megamphopus.* I am therefore naming this genus *Neomegamphopus* in order to call attention to its resemblance to the genus *Megamphopus,* and I am placing it in the family Photidae, to which I am of the opinion an emendation should be made in order to accommodate this genus having the first gnathopods larger than the second in the male.

CHEVALIA AVICULAE Walker

Chevalia aviculae WALKER, 1904, Rep. Pearl Oyster Fisheries, Gulf of Manaar, Suppl. Rep. 27, Amphipoda, p. 288, pl. 7, fig. 50; pl. 8, fig. 50.
Neophotis inaequalis STOUT, 1913, Zool. Jahrb., Abt. Syst., vol. 34, p. 653.

Station 3. Magdalena Bay, Lower California, 5 specimens.

Chevalia aviculae was described from the Gulf of Manaar, between Ceylon and India in 1904. In 1909 Walker again recorded it from the Seychelles Islands. It was recorded from South Africa by Barnard in 1916. In 1921 I recorded it from Barbados, West Indies. Barnard recorded it in 1937 from the Red Sea and the south coast of Arabia.

Prof. A. S. Pearse in 1912 described the species *Chevalia mexicana* from the Gulf of Mexico, but this is undoubtedly a synonym of the earlier species, many of the characters of which appear to be rather variable.

In 1913 Vinnie Ream Stout described a new genus and species of amphipod, *Neophotis inaequalis,* from Laguna Beach, Orange County, Calif., but gave no figures. There are no specimens of her species extant, but her description leaves no doubt that she was dealing with *Chevalia aviculae* Walker which occurs in southern California.

The present record from Magdalena Bay is the first definite one for the west coast of America, as Miss Stout's species had not heretofore been recognized as a synonym of Walker's *C. aviculae.* The National Museum also possesses specimens of *Chevalia aviculae* from kelp holdfasts pulled up off South Coronado Island, northern Lower California, and from Corona Del Mar, Orange County, Calif.

AMPITHOIDAE

AMPITHOE PLUMULOSA Shoemaker

Ampithoe plumulosa SHOEMAKER, 1938, Journ. Washington Acad. Sci., vol. 28, No. 1, p. 16, fig. 1.

Station 3. Magdalena Bay, Lower California, 15 specimens.

Station 4. Magdalena Bay, Lower California, 1 specimen.

Station 5. Cape San Lucas, Lower California, 4 specimens.

Station 9. Clipperton Island (shore collecting), 1 specimen.

This species was described from a tide pool at La Jolla, southern California, in 1938, and its range was given as extending from Ecuador northward to Strait of Georgia, British Columbia. Clipperton Island, which lies between 600 and 700 miles off the west coast of Mexico, is a new locality for the species.

AMPITHOE RAMONDI (Audouin)

Amphithoe ramondi AUDOUIN, 1826, Descr. Égypte, Nat. Hist., vol. 1, pt. 4, p. 93; Savigny, Crustace et Arachnides de l'Egypte, pl. 11, fig. 6♀.

Ampithoe ramondi SCHELLENBERG, 1928, Trans. Zool. Soc. London, vol. 22, pt. 5, p. 665.

Ampithoe simulans ALDERMAN, 1936, Univ. California Publ. Zool., vol. 41, No. 7, p. 68, figs. 44-47.

Station 3. Magdalena Bay, Lower California, 16 specimens.

Station 30. Old Providence Island, Caribbean Sea, 2 specimens.

This widely distributed species varies considerably in the detail of several of its characters. The frontal lobes of the second and third joints of the first and second gnathopods and the palm of the second gnathopod of the male are particularly subject to variation. *Ampithoe vaillanti* (Lucas) described from the Mediterranean is now also considered a synonym of *A. ramondi* (Audouin).

This species is cosmopolitan in the tropical and subtropical seas. It was described from the Mediterranean and has since been recorded from the Suez Canal; South Arabian coast; Gulf of Manaar, Indian Ocean; East Indies; North and South Pacific; Pacific coast of North America; tropical Atlantic; and South Africa.

ISCHYROCERIDAE [3]

JASSA FALCATA (Montagu)

Cancer (Gammarus) falcatus MONTAGU, 1808, Trans. Linn. Soc., vol. 9, p. 100, pl. 5, figs. 1-2.

Podocerus falcatus SARS, 1895, Crustacea of Norway. Amphipoda, vol. 1, p. 594, pl. 212.

Jassa falcata SEXTON, 1911, Journ. Marine Biol. Assoc., vol. 9, No. 2, p. 212.

Station 3. Magdalena Bay, Lower California, 3 specimens.

Jassa falcata was described from the coast of England over 100 years ago, and since then it has been recorded from tropical and temperate waters around the globe. As the male appears to vary considerably at different stages of its development, the animal has been described under several different names by different authors (Sexton, 1911, p. 212). It was recorded by Chilton (1921, p. 89) from Juan Fernandez, but the present record is the first for the west coast of North America.

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[3] I am using the family name Ischyroceridae created by Stebbing in 1899 in place of the name Jassidae, preoccupied by Fieber in 1866 for a family of Hemiptera (Shoemaker 1920, p. 22).

PARAJASSA ANGULARIS, new species

FIGURES 14, 15

Station 3. Magdalena Bay, Lower California, 3 specimens.

Male.—Head with side lobes considerably produced. Eye oval and black. Antenna 1, first joint of peduncle slightly shorter than third, which is a little shorter than second; flagellum about half as long as peduncle and 6-jointed, each joint bearing a slender sense organ. Antenna 2 stouter but subequal in length to antenna 1, fourth joint of peduncle slightly shorter than fifth; flagellum about equal in length to fourth joint and consisting of one long and three shorter joints.

Epistome produced into a long sharp point. Mandible with molar rather prominent; only two toothed or serrate spines in spine row; palp rather long, third joint shorter than second. Maxilla 1, inner plate small, narrowly angular and without setae; outer plate armed with nine spine teeth; palp very large, armed distally with six serrate spine teeth and six or seven setae. Maxilla 2, outer plate longer and wider than inner. Maxillipeds, inner plate nearly as long as outer, armed distally with three serrate spine teeth, and bearing an inward-pointing spine on the outer surface near the inner margin; outer plate reaching to about the middle of the second joint of palp, armed on the inner margin with five simple spine teeth and a few setae; palp slender, third joint much shorter than second, fourth joint shorter than third and armed distally with four curved spines. Lower lip with inner lobes very large.

Gnathopod 1, coxal plate somewhat produced forward with sides converging distally; second joint longer than either fifth or sixth; fifth joint slightly shorter than sixth; sixth joint about twice as long as wide, palm slightly oblique, very finely serrate and defined by a well-marked angle, hind margin of joint bearing three notched spines and two groups of slender spines; seventh joint considerably overlapping palm, inner margin finely serrate, and bearing a prominent tooth near the apex. Gnathopod 2 large and strong; coxal plate longer than deep; second joint greatly expanded; third joint bearing a narrow front lobe; fifth joint bearing a broad posterior lobe; sixth joint very robust, about a third longer than wide with a short tooth near the middle of the hind margin, palm transverse, very short and defined by a right angle; seventh joint stout, closing partly on the inside surface of the sixth joint with the apex resting in the angle made by the marginal tooth and the hind margin of sixth joint, inner edge of seventh joint armed with about 12 very short blunt spines.

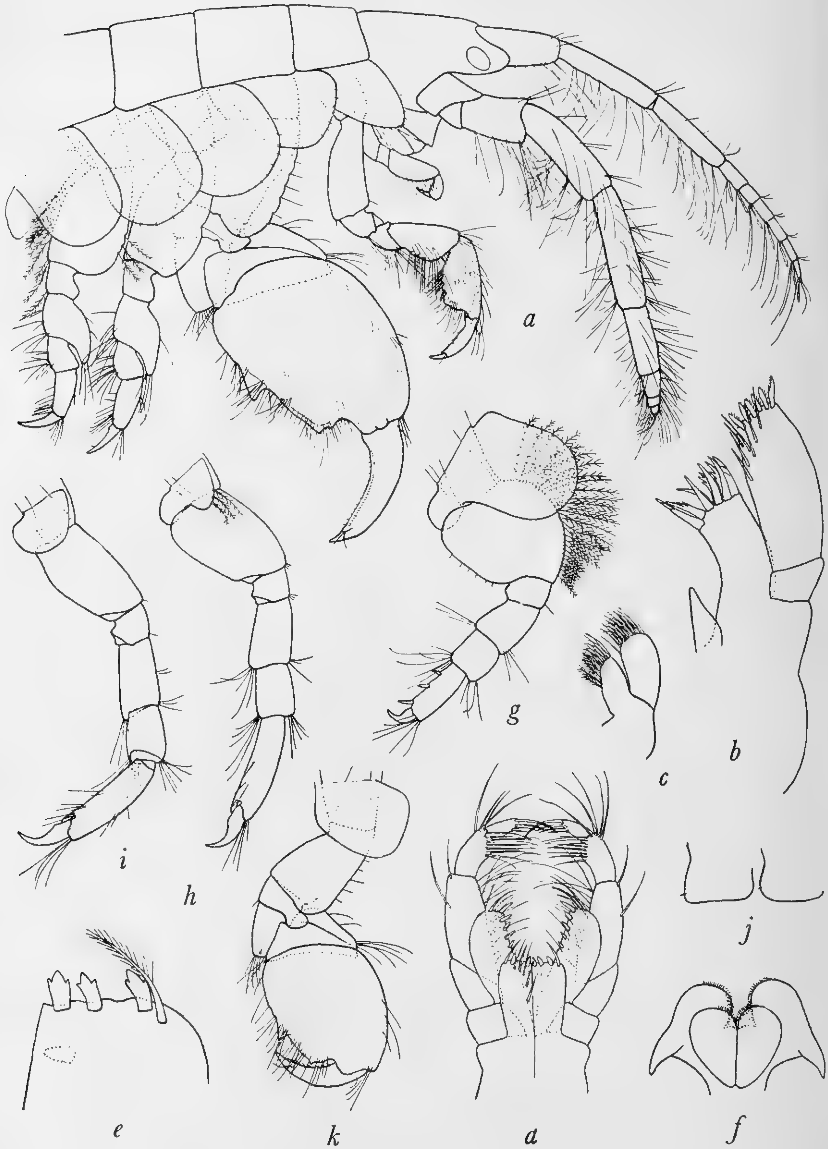

FIG. 14.—*Parajassa angularis*, new species. Male, *a*, front half of animal; *b*, maxilla 1; *c*, maxilla 2; *d*, maxillipeds; *e*, inner plate of maxilliped showing the three spine teeth; *f*, lower lip; *g*, peraeopod 3; *h*, peraeopod 4; *i*, peraeopod 5; *j*, second and third metasome segments. Female, *k*, gnathopod 2.

Peraeopods 1 and 2 subequal in length and very much alike in structure; second joint considerably expanded; fourth joint expanded and produced anteriorly into a downward-pointing lobe which reaches to the lower margin of the fifth joint. Peraeopod 3, coxal plate not quite as deep as those of peraeopods 1 and 2. Peraeopods 3 to 5 in-

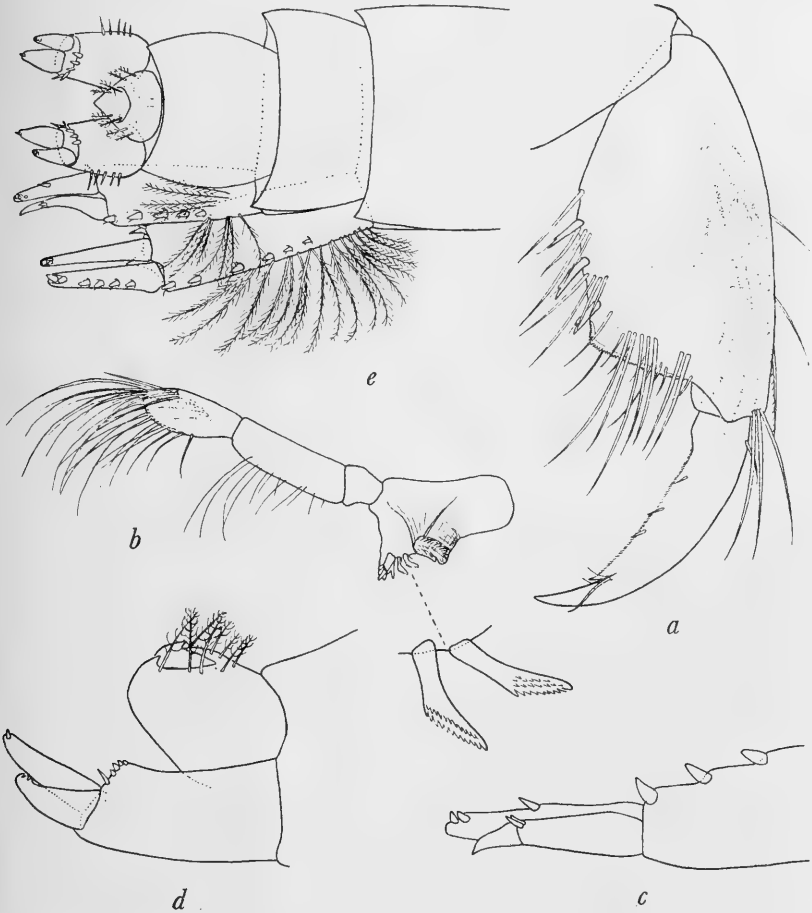

FIG. 15.—*Parajassa angularis,* new species. Male, *a,* gnathopod 1; *b,* mandible; *c,* uropod 2; *d,* uropod 3 and telson.

creasing in length consecutively and proportioned as shown in figure 14, *g-i.* Metasome segments with lower hind corners broadly rounding. Uropod 3 not extending back quite as far as 2. Uropod 2, outer ramus viewed from above curving outward, the distal quarter of ramus downward-pointing, transparent and having the appearance of a second joint at the base of which are two small spines. Uropod 3, outer ramus shorter than inner and bearing apically three minute hooked spines. Telson triangular viewed from above, bearing two hooks near the apex and several plumose setules on upper surface. Length, from front of head to end of uropod 3, 4 mm.

Female.—Very much like the male, differing principally in gnathopod 2, which is much the same shape as in the male, but proportionally smaller. Length of the female is a little less than that of the male.

Type locality.—Magdalena Bay, Lower California, dredged in 10-15 fathoms inside northern point of entrance to bay, July 18, 1938. Holotype, male, U.S.N.M. No. 79379.

MICROJASSA MACROCOXA, new species

FIGURES 16, 17

Station 3. Magdalena Bay, Lower California, 30 specimens.

Station 4. Magdalena Bay, Lower California, 1 specimen.

Male.—Head cut far back below for the insertion of the base of antenna 2; side lobes produced and angular. Eye rather large, colorless, but facets plainly visible. Antenna 1 short, second joint longest; flagellum 2-jointed, first joint very long; accessory flagellum 1-jointed. Antenna 2 more than twice as long as antenna 1, fifth joint longest; flagellum 2-jointed, first joint very long.

Right mandible, accessory plate toothed; two spines in spine row; molar well developed, with a little denticulate plate in a recess of the forward margin and a long seta attached to the inner margin; palp well developed, second joint longest; third joint narrower than second and distally truncate. Maxilla 1, inner plate undiscoverable or absent; outer plate bearing seven spine teeth; second palp joint long and armed distally with five spine teeth and a very oblique row of four setae. Maxilla 2, inner plate shorter and narrower than outer. Maxillipeds, inner plate about half the length of the outer, armed on apical margin with one spine tooth and on the under surface with one stout tooth which points toward the inner margin; outer plate with inner crenate margin bearing four spine teeth, apical margin bearing one curved spine tooth and three plumose or pectinate spines; third joint of palp bearing an oblique row of spines; fourth joint with long slender pectinate nail. Lower lip much as figured by Sars (pl. 212, *l*) for *Jassa falcata,* but inner lobes and side lobes very well developed.

Gnathopod 1, coxal plate not much deeper than its body segment, not as long as deep; second joint as long as the fifth and sixth joints

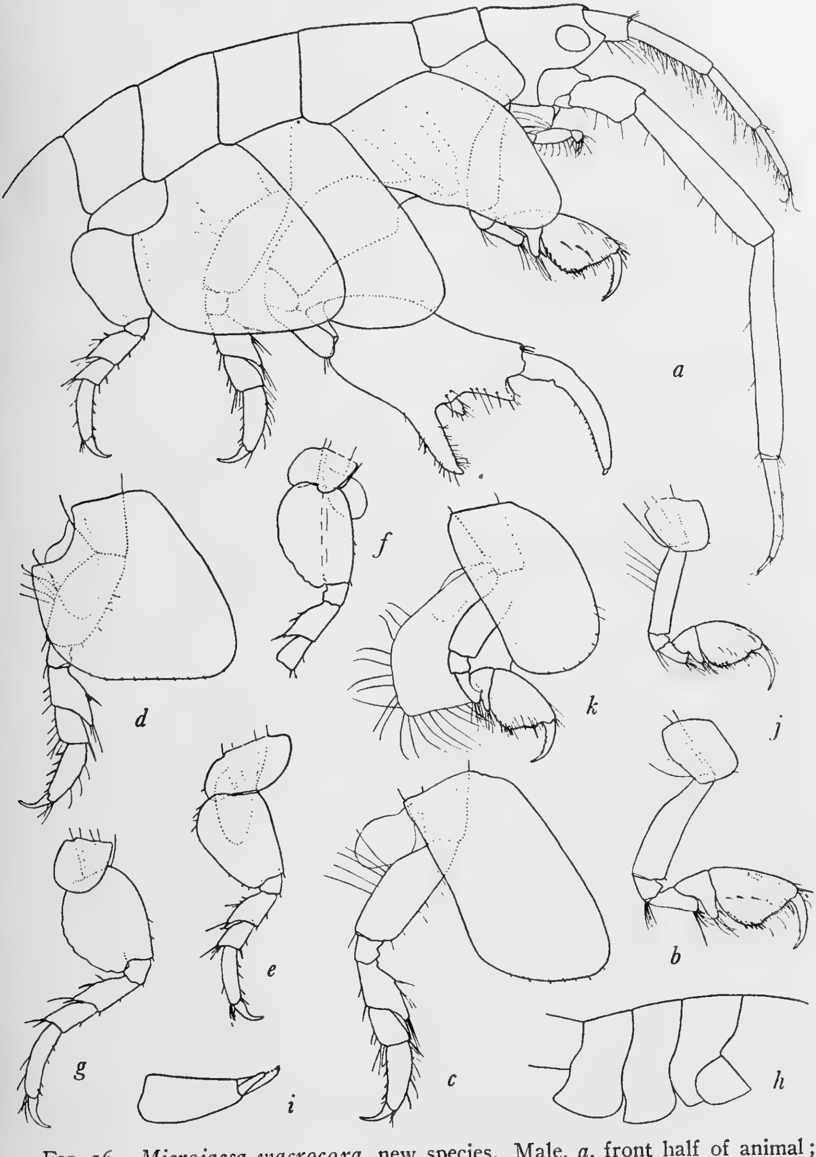

FIG. 16.—*Microjassa macrocoxa*, new species. Male, *a*, front half of animal; *b*, gnathopod 1; *c*, peraeopod 1; *d*, peraeopod 2; *e*, peraeopod 3; *f*, peraeopod 4; *g*, peraeopod 5; *h*, metasome; *i*, uropod 3, inside view of right. Female, *j*, gnathopod 1; *k*, gnathopod 2.

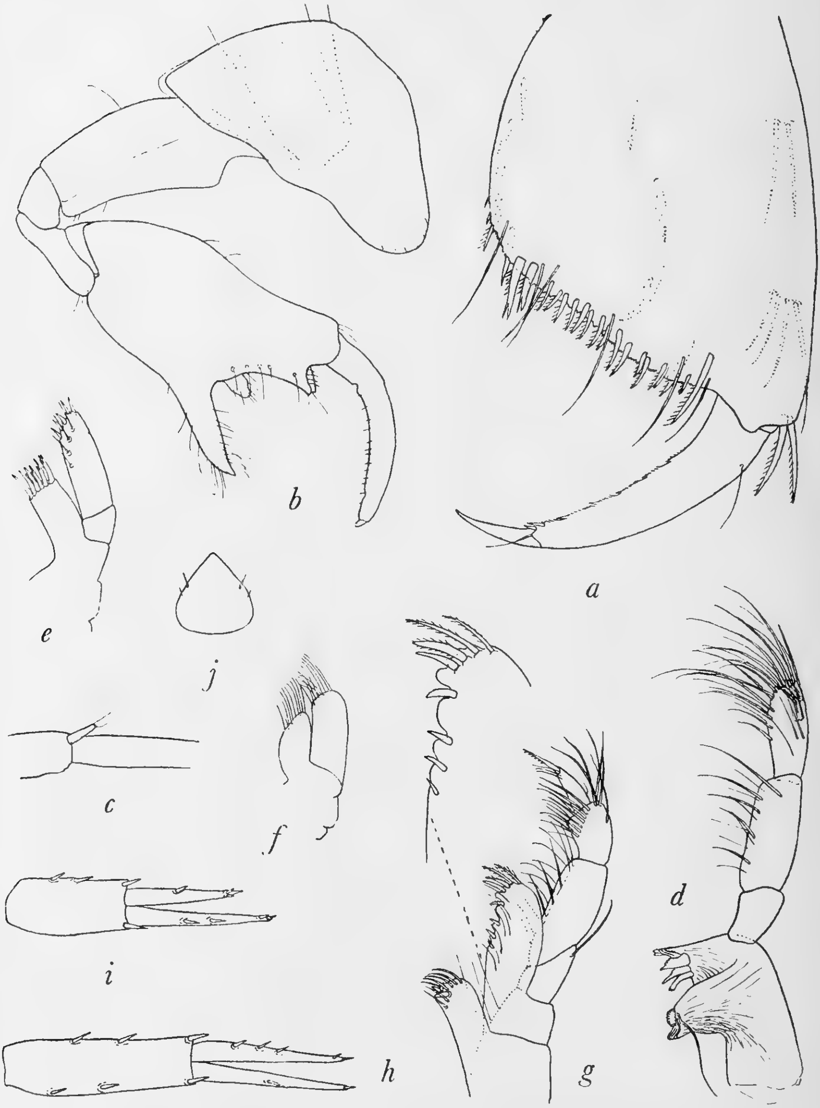

FIG. 17.—*Microjassa macrocoxa*, new species. Male, *a*, gnathopod 1, greatly enlarged; *b*, gnathopod 2; *c*, accessory flagellum; *d*, mandible; *e*, maxilla 1; *f*, maxilla 2; *g*, maxilliped; *h*, uropod 1; *i*, uropod 2; *j*, telson.

combined; sixth joint wider than fifth, palm oblique and passing into hind margin by a broadly rounding curve, but defined by two stout pectinate spines, edge of palm crenulate and serrulate; seventh joint with inner margin serrulate. Gnathopod 2, coxal plate strongly developed, not as long as deep, narrowing distally to the evenly rounding lower margin; second joint with proximal end very narrow, then becoming strong and widening abruptly, leaving the front margin deeply concave for the reception of the fifth and sixth joints when the limb is folded against the body; fifth joint very short, sixth joint powerful with hind margin produced distally into a long, strong tooth, palm greatly excavate with a short central tooth and a more prominent one near the distal hinge; seventh joint stout and bearing a minute nail, inner margin bearing a very low tooth preceded by a shallow indentation.

Peraeopod 1 rather short and stout, but a little longer than 2; coxal plate deeper than the preceding or following, twice as deep as long and a little wider distally. Peraeopod 2 much like 1, coxal plate about as deep as long and very deeply excavate behind. Peraeopod 3 shorter than 2. Peraeopods 4 and 5 about equal in length and longer than 3.

Metasome, segment 2 the deepest, the lower hind corner of segments 2 and 3 slightly produced. Uropods 1 and 2 slender; uropod 2 projecting a little farther back than 1, and uropod 3 perhaps a little farther back than 2. Outer ramus of uropod 1 very slightly shorter than inner; outer ramus of uropod 2 much shorter than inner. Uropod 3, peduncle twice as long as outer ramus which is longer than the inner; outer ramus bears very minute serrulations on upper margin near the apex. Telson reaches to about the center of the peduncle of uropod 3, about as wide as long with sides converging to the narrow, pointed apex. Length of male about 3.5 mm.; female a little smaller.

Female.—Antennae are shorter than in the male. Coxal plates are not quite as deep as in male. Gnathopod 1 much like that of male, but palm more oblique. Gnathopod 2 much like gnathopod 1 of male, but the palm more sinuous, and the coxal plate with front and hind margins about parallel.

Type locality.—Magdalena Bay, Lower California, dredged in 10-15 fathoms inside northern point of entrance to bay, July 18, 1938. Holotype, male, U.S.N.M. No. 79369.

COROPHIIDAE

ERICTHONIUS BRASILIENSIS (Dana)

Pyctilus brasiliensis Dana, 1853 and 1855, U.S. Explor. Exped., vol. 14, pt. 2, Amphipoda, p. 976, pl. 67, fig. 5, *a-h*.

Ericthonius abditus Sars, 1895, Crustacea of Norway. Amphipoda, vol. 1, p. 602, pl. 215.

Ericthonius brasiliensis Stebbing, 1906, Amphipoda. I. Gammaridea, Das Tierreich, p. 671.

Station 3, Magdalena Bay, Lower California, many specimens.

This is a cosmopolitan species, inhabiting the warm and temperate seas of the globe. It was recorded by Stimpson from San Francisco Bay as *Ericthonius rapax* in 1857. The species is rather variable and has been described by different authors under different names. *E. minax,* described by Smith from New England, and *E. disjunctus,* described by Stout from Laguna Beach, Calif., are synonyms of *E. brasiliensis* (Dana).

CERAPUS TUBULARIS Say

Cerapus tubularis Say, 1817, Journ. Acad. Nat. Sci., Philadelphia, vol. 1, No. 4, pp. 50, 96, pl. 4, figs. 7-11.

Cerapus tubularis Kunkel, 1918, State of Connecticut State Geol. and Nat. Hist. Surv., Bull. 26, p. 160, fig. 48.

Station 3. Magdalena Bay, Lower California, 2 specimens.

Station 5. Cape San Lucas, Lower California, 2 specimens.

Cerapus tubularis was described by Say from Egg Harbor, N. J., and appears to be fairly common on the east coast of the United States. The animal constructs a slender, dark-colored tube, open at both ends, in which it lives and which it carries about. Prof. S. I. Smith (Trans. Connecticut Acad., vol. 4, pp. 269-277) has given a description and observations on the habits of this species. It has not heretofore been recorded from the west coast of America.

PODOCERIDAE

PODOCERUS CRISTATUS (Thomson)

Cyrtophium cristatum G. M. Thomson, 1879, Ann. Mag. Nat. Hist., ser. 5, vol. 4, No. 23, p. 331, pl. 16, figs. 9-15.

Cyrtophium dentatum Haswell, 1879, Proc. Linn. Soc. New South Wales, vol. 4, p. 342, pl. 22, fig. 5.

Podocerus cristatus Chilton, 1926, Trans. New Zealand Inst., vol. 56, pp. 513-515, fig. 2.

Station 3. Magdalena Bay, Lower California, 12 specimens.

Station 4. Magdalena Bay, Lower California, 1 specimen.

This species was described from New Zealand in 1879 and has since been recorded from Australia, South Africa, and West Africa. It is now recorded for the first time from the west coast of North America.

CYAMIDEA

CAPRELLIDAE

CAPRELLA SCAURA Templeton

Caprella scaura Templeton, 1836, Trans. Ent. Soc. London, vol. 1, pt. 3, p. 191, pl. 20, fig. 6.

Caprella scaura Barnard, 1925, Ann. South African Mus., vol. 20, No. 8, p. 371.

Station 3. Magdalena Bay, Lower California, many specimens.

Station 4. Magdalena Bay, Lower California, many specimens.

Station 5. Cape San Lucas, Lower California, 4 specimens.

This variable species was described from Mauritius and has since been recorded from the east coast of Asia, west coast of North and South America, east coast of South America, West Indies, east coast of North America, and South Africa.

HYPERIIDEA

HYPERIIDAE

HYPERIA BENGALENSIS (Giles)

Lestrigonus bengalensis Giles, 1887, Journ. Asiatic Soc. Bengal, vol. 56, pt. 2, p. 224.

Hyperia bengalensis Walker, 1904, Pearl Oyster Fisheries, Gulf of Manaar, Suppl. Rep. 17, Amphipoda, p. 235.

Hyperia bengalensis Pirlot, 1939, Résult. Camp. Sci., fasc. 102, p. 35.

Station 22. Off Gardner Bay, Hood Island, Galápagos Islands, 1 specimen.

As shown by Pirlot's synonymy, this small species has been described under many different names from widely separated localities. It has been recorded from the Mediterranean, Indian Ocean, East Indies, New Zealand, and North and South Atlantic. The present record is the first for the Galápagos Islands.

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SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 101, NUMBER 12

THE QUANTITY OF VAPOROUS WATER IN THE ATMOSPHERE

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The late F. E. Fowle published several papers descriptive of the establishment and applications of a spectrobolometric method to determine how thick a stratum of liquid water would be produced if all the water vapor in the atmosphere could be instantaneously precipitated.[1] As we practice it, the method employs the quantity ρ/ρ sc. By this symbol we designate the ratio between the ordinate at the bottom of the great water-vapor band ρ, seen as a depression in a bolograph of the upper infrared spectrum, and the ordinate of the smooth curve drawn across the top of the band and measured at the same place in abscissae. At each of our solar-constant stations we have worked out an empirical relationship of the same sort as explained by Fowle[1] between ρ/ρ sc and the quantity of precipitable water vapor (termed, for short, "precipitable water"). He at first used ϕ/ϕ sc and ψ'/ψ' sc, but later himself frequently employed ρ/ρ sc as we do. The precipitable water thus determined includes all of the water vapor in a column of atmosphere from the station outward to the limit of the atmosphere in the direction of the sun. The length of such a column, as compared to a vertical one, is given by the "air mass." For solar-zenith distances less than 70° where the value is approximately 3.0, the air mass is approximately secant Z, where Z is the angular distance of the sun from the zenith. Hence if w_m is the precipitable water measured at air mass m, the value w_1 corresponding to zenith sun, and representing the thickness of liquid water which would fall uniformly upon the earth at the given locality, is $\frac{w_m}{m}$.

The quantity of precipitable water in the atmosphere is a value of great meteorological significance, but one for which at present there are no means generally available to measure. Accordingly it seemed useful to assemble the results from the numerous spectrobolometric determinations of the solar constant of radiation, as measured at several stations of the Smithsonian Institution during the last 30 years. It will be understood that though these determinations of precipitable water have been made at all seasons of the year, at stations

[1] Astrophys. Journ., vol. 35, p. 149, 1912; vol. 37, p. 359, 1913.

ranging from 5,000 to 9,000 feet altitude, and in days of different meteorological conditions of the atmosphere, they must nevertheless have been made only on days when the sun shone, and the sky was fairly free of clouds. It will be difficultly comprehensible to some that the precipitable-water values given below are generally so low when compared with the actual depths of rain which fall on many occasions. Our stations have been located in far-separated regions of the earth, so that the results given here must fairly well represent fair-weather conditions of the atmosphere above 5,000 feet the world over. How, then, it will be asked, can rainfalls many times as deep as the precipitable water occur?

This is partly accounted for by the consideration that the values to be given here generally relate to stations above 5,000 feet in altitude. It is well known that the lower atmosphere is comparatively rich in water vapor. Our Washington observations, practically at sea level, were all made before Fowle worked out this precipitable-water method. We cannot now obtain precipitable-water values corresponding to all of the Washington observations given in table 14, volume 2 of the Annals of the Astrophysical Observatory. However, to give at least a rough idea of what these Washington observations might have disclosed, my colleague, Mr. Aldrich, has kindly reduced for me, as well as can be done after many years, the indications from measurements he has made on 59 Washington bolographic curves still preserved at the Astrophysical Observatory. These results, given below, indicate roughly the average precipitable water at sea level for the four seasons at latitude 39° N.

Another consideration tending to reconcile rainfall with precipitable water values is that during a rainfall or snowfall, atmospheric circulation may sweep into the path of the storm a considerable part of the atmospheric-water load from much larger areas, outside the region of actual precipitation. Thus by the partial denudation of water vapor from large surrounding areas, smaller areas of the atmosphere may be provided with quantities of precipitable water several, or even many, times as great as they normally contain. When a storm advances over paths many hundreds of miles long, as for instance from the Gulf of Mexico to Washington, we are not, of course, to imagine that water gathered in the Gulf of Mexico during the earlier part of the storm is carried by clouds to Washington to fall there later on. It is rather a state of atmospheric disturbance which travels, producing clouds along the way and precipitating local supplies of moisture for local rains all along the path. It is not at all, in other words, as if one dipped a bucket in the Gulf of Mexico and, carrying it to Washington, emptied it there.

Hoping that meteorologists will welcome these precipitable-water data, as of a kind perhaps attainable only from Smithsonian solar radiation observations, I now give, in addition to the Washington results referred to above, numerical data computed by Miss N. M. McCandlish from the tabular results of various solar-constant investigations published in volumes 3, 4, 5, and 6 (now in press) of the Annals of the Astrophysical Observatory. It will be understood that the term "precipitable water" and the symbol w_1 as used below, refer in every case to the quantity of precipitable water found in a vertical column of atmosphere above the station stated.

The unit for precipitable water, w_1 in the following tables is 1/10 of 1 millimeter of liquid water. The average deviation from the mean, Δw_1, is given in the same units. In addition, I give the probable error of w_1 in percentage. It is computed as $\frac{0.84}{\sqrt{n}} \times \frac{\Delta w_1}{w_1} \times 100$, where n is the number of years included in the mean monthly values.

Station: Montezuma, Chile
Lat. 22°40′ S., long. 68°56′ W., alt. 8,895 ft.
Interval covered, September 1923 to September 1939
Fair days only
Monthly mean values of precipitable water, average deviation, and percentage probable error

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
w_1	92	99	85	42	34	25	22	22	27	30	35	52
Δw_1	20	24	17	7	6	3	4	5	6	7	8	12
P.e.%	4.5	5.1	4.1	3.4	3.8	2.4	3.9	4.7	4.7	4.8	4.5	4.9

From Montezuma, for the interval stated above, I give also the numbers of days during months of the year when precipitable water, w_1 of 0.5 millimeter or less was observed, and also the months when precipitable water of 15.0 millimeters or more was observed. The maximum value found at Montezuma during fair days was 19.4 millimeters. In the following table, the unit is still 1/10 of 1 millimeter.

Numbers of fair days, 1923-39, when precipitable water had certain values

w_1	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
5	...	...	1	1	3	5	4	4	7	...	1	...
4	...	...	...	...	2	3	4	5	4	1	...	...
3	...	...	...	...	...	5	1	2	4	...	...	...
2	...	...	...	...	...	2	2	2	...	...	...	...
1	...	...	...	...	...	1	...	...	...	...	...	...
>15.0	12	14	10	...	...	...	...	...	...	...	...	...

Station: Table Mountain, Calif.
Lat. 34°22′ N., long. 117°41′ W., alt. 7,500 ft.

Interval covered, January 1926 to September 1939

Fair days only

Monthly mean values of precipitable water, average deviation, and percentage probable error

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
w_1	30	26	37	37	46	54	68	77	54	50	39	31
Δw_1	4	5	8	7	7	9	16	17	12	6	8	4
P.e.%	3.2	4.7	4.8	4.6	3.4	3.6	5.2	5.1	5.0	3.0	4.6	2.8

Station: St. Katherine, Egypt
Lat. 28°31′ N., long. 33°56′ E., alt. 8,500 ft.

Interval covered, January 1934 to November 1937

Fair days only

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
w_1	14	16	18	17	28	28	31	34	27	35	30	22
Δw_1	2.5	3.5	1.7	1.2	5.0	4.2	3.2	6.5	3.2	4.7	4.0	1.7
P.e.% [a]	7.5	9.2	3.9	3.0	7.6	6.3	4.3	8.0	5.0	5.6	5.6	3.2

[a] The larger % probable errors, compared to Montezuma and Table Mountain, are due to the shorter interval.

Station: Harqua Hala, Ariz.
Lat. 33°48′ N., long. 113°20′ W., alt. 5,646 ft.

Interval covered, October 1920 to October 1925

Fair days only

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
w_1	27	34	31	41	55	76	162	158	84	52	42	38
Δw_1	3.8	4.2	4.2	4.4	6.2	12.2	15.0	8.0	22.2	10.3	2.8	4.6
P.e.% [a]	5.3	4.7	5.1	4.0	4.2	6.0	3.5	1.9	9.8	6.8	2.5	4.5

[a] The larger % probable errors, compared to Montezuma and Table Mountain, are due to the shorter interval.

Station: Mount Wilson, Calif.
Lat. 34°13′ N., long. 118°04′ W., alt. 5,665 ft.

Interval covered, spring, summer, and autumn months, 1910 to 1920

Fair days only

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
w_1	...	...	...	28 [a]	70	82	117	111	92	84	51	...
Δw_1	...	...	...	...	4 [b]	21	19	10	17	11	4 [b]	...
P.e.%	...	...	...	...	...	7.6	4.2	2.3	4.8	3.7	...	...

[a] One day only.
[b] Few years observed

Station: Mount Brukkaros, S.W. Africa
Lat. 25°52′ S., long. 17°48′ E., alt. 5,202 ft.

Interval covered, December 1926 to November 1928

Fair days only

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
w_1	146	181	197	142	104	75	60	62	70	82	104	142
Δw_1	8	28	11	6	16	13	5	7	9	12	11	16
P.e.%	Years too few for probable error.											

Station: Hump Mountain, N. C.
Lat. 36°08′ N., long. 82°00′ W., alt. 4,921 ft.

Interval covered, June 1917 to March 1918

Fair days only

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
w_1	19	38	22	...	...	52	131	92	72	71	48	57

Station: Washington, D. C.
Lat. 38°53′ N., long. 77°02′ W., alt. 30 ft.

Interval covered, July 1904 to April 1906

Averages of a few fair days only [a]

	Winter	Spring	Summer	Autumn
w_1	61	190	215	167

[a] On each of these days, however, several bolographs were taken at different air masses, each yielding independently a value of w_1. These independent observations on the same day agreed very well, and their mean values were used in computing the results given here.

Comparing the five stations, Montezuma, Table Mountain, Mount St. Katherine, Harqua Hala, and Mount Wilson, for all of which a considerable number of years of observation are available, we note certain interesting features.

The atmosphere above Mount St. Katherine, lying in the great desert belt of the Northern Hemisphere, between Arabia and the Sahara, is dryer than any of the others, and shows much less percentage range of precipitable water as between summer and winter than the other stations. Were it not for the war, and for the excessive isolation and the tendency to intestinal sickness there, Mount St. Katherine would be exceptionally well suited to solar-constant measurements.

Although a little higher than Mount St. Katherine, Montezuma, lying 6° nearer the Equator, is under an atmosphere considerably richer in water vapor. There is also a wide range of humidity as between summer and winter. Our experience has indicated that the moist summer months there are a little disappointing as regards both number and quality of solar-constant observations. It is thought, however, that meteorologists will note with surprise and interest how many days have been found there in winter when the entire superincumbent atmosphere contains less than $\frac{1}{2}$ of 1 millimeter of precipitable water.

Table Mountain shows much less range of humidity as between summer and winter than Harqua Hala, where summer thunderstorms prevail. Mount Wilson, also, shows a considerably less summer humidity than Harqua Hala, though much more than Table Mountain, which is both 900 feet higher and lies nearer the Mojave Desert.

Washington, at sea level, shows, of course, the great concentration of water vapor in the lower atmosphere. Lying, however, in latitude 39° N., Washington does not give a full indication of the precipitable water which would be found at sea level within the Tropics. It would, indeed, be very interesting if a series of spectroscopic measurements of the quantity could be made at the Canal Zone or in tropical South America. The United States Weather Bureau has an instrument designed and constructed for such measurements by the Smithsonian Institution.[2] One may hope that it may be practicable for them to conduct a series of precipitable-water measurements with it at the Canal Zone.

THE MARCH OF PRECIPITABLE WATER AT TIMES OF RAINFALL

It might be supposed that rains would be presaged by decided increase of atmospheric humidity for several days, and that such changes of humidity, being readily measured by spectrobolometric observations, could serve as a means of predicting the approach and the probable amount of rainfall, for several days in advance.

To investigate this probability I have examined the run of precipitable water and of rainfall at Harqua Hala and at Hump Mountain. For Harqua Hala I made a comparison with the rainfall at Phoenix, Ariz., and for Hump Mountain with Asheville, N. C. At Harqua Hala I noted the variations of precipitable water near the dates of every rainfall which at Phoenix exceeded 0.05 inch from October 1920 to October 1924, and at Hump Mountain I compared precipitable-water data for the 10 months June 1917 to March 1918 with Asheville rainfall.

These studies led to a negative conclusion. There was found no general relationship or certain connection between the march of pre-

[2] See U. S. Monthly Weather Rev., vol. 68, p. 95, April 1940.

cipitable water from day to day and the fall of rain. It appeared that if notable changes of precipitable water preceded and followed rains, such changes must generally have taken place only within a few hours of rainfall, when the sky was probably too cloudy for spectrobolometric observations. Certainly there was no definite change of precipitable water considerably antedating rainfalls which could serve for forecasting their times and amounts.

This tends to support the view advanced earlier in this paper, namely, that the approach of a rainstorm is not accompanied by any considerable transport of water from the direction whence the storm comes. What occurs is a traveling disturbance of the atmosphere, which, as it reaches successive localities, draws together from short distances aqueous vapor already suspended within the atmosphere in those regions. This view is supported by the observation which I made that on the day next following a rainfall the precipitable water is apt to be less than that which usually prevails at that time of the year.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 101, NUMBER 13

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(WITH THREE PLATES)

BY
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During the summer of 1940 a laborer, while fishing, discovered portions of a fossil jaw in the bank of a small stream on the Covington Farm south of Quitman, Miss. Fortunately, through the kindness of V. G. Clifford, of Quitman, the material was brought to the attention of Professor Sullivan at Millsaps College. Recognizing the remains as titanothere and realizing their significance, Professor Sullivan immediately investigated the occurrence with the result that the skull was also recovered. No other skeletal portions were found. Later, Professor Sullivan communicated with Dr. Remington Kellogg and C. W. Gilmore, and arrangement was made for preparation in the laboratory of vertebrate paleontology at the United States National Museum. The specimen has been deposited with the National Museum.

The remains were found about 2½ miles south of Quitman, Clarke County, on a small branch of a tributary to the Chickasawhay River. On the Geologic Map of Mississippi compiled by Dr. L. W. Stephenson[1] the place of its occurrence is seen to be well within the area mapped as immediately underlain by the Lisbon formation. Dr. Julia Gardner of the United States Geological Survey has made collections from the vicinity of the find and informs us that the distribution of Lisbon beds certainly includes the area in question. The Lisbon is a part of the Claiborne group, and is the equivalent of the Cook Mountain formation farther west. These beds are currently regarded as of about middle Eocene age.

[1] Accompanying U. S. Geol. Surv. Water Supply Paper 576, 1928.

For the identification of the beds as Lisbon, we are indebted to F. Stearns MacNeil, of the United States Geological Survey, who has recently examined the site. MacNeil reports that the rock from which the titanothere came contains an abundance of invertebrate remains, including *Ostrea sellaeformis,* which is characteristic of the Lisbon. Further substantiating evidence is to be found in the work of Dr. R. E. Grim,[2] of the University of Mississippi.

The mollusks collected by MacNeil from the margin of the excavation made for the skull were submitted to Dr. Julia Gardner for identification. Her report is as follows:

> The following species were recognized in the material associated with the skull collected $2\frac{1}{2}$ miles south of Quitman, Clarke County, Mississippi:
>
> *Nucula* sp.
> *Chlamys* sp. cf. *C. wahtubbeanus* Dall
> *Pseudamussium corneoides* Harris
> *Nemocardium* sp.
>
> *Ostrea sellaeformis* Conrad was reported from a level not more than a foot below the skull horizon. The character of the material and of the fauna closely resembles that of Bed No. 17 of the Little Stave Creek section in Clarke County, Alabama. On Little Stave Creek, Bed No. 17 occurs about 25 feet below the top of the Lisbon.

The foraminifera included with the above samples taken from the margin of the excavation were prepared by Lloyd G. Henbest and submitted for identification to Dr. Joseph A. Cushman. His report is as follows:

> The specimens you [Henbest] sent from the Eocene $2\frac{1}{2}$ miles south of Quitman, Clarke County, Miss., have been examined and they contain numerous species which seem to place the material definitely in the Claiborne. Two of these, *Siphonina claibornensis* Cushman and *Nonion planatum* Cushman and Thomas, are abundant.
>
> In addition there are numerous species described by Howe from the Cook Mountain Eocene of Louisiana: *Pseudobulimina glaessneri* Howe and Roberts, *Nonionella winniana* Howe, *Triloculina natchitochensis* Howe, etc., that give enough evidence, I believe, to place the sample definitely in this part of the Claiborne.

The titanothere find is particularly significant in two respects: first, in permitting a tie-in between the continental sequence of the Rocky Mountain and Great Plains areas and the marine Eocene of the Gulf Coastal Plain; and second, in the discovery of a new member of the Brontotheriidae and at a place in the southern States remote from the recorded distribution of titanotheres, either Eocene or Oligocene.

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[2] Mississippi State Geol. Surv. Bull. 30, p. 130, 1936.

The evidence for correlation is presented by the stage of evolution exhibited by the skull and dentition of the Mississippi titanothere, comparisons being greatly facilitated by the tremendous amount of change that took place in the titanothere family during the period from lower Eocene to lower Oligocene time. The Mississippi form seems most nearly comparable to the stage of development reached in the late Uintan titanotheres, currently regarded as upper Eocene, or possibly the Duchesnean forms usually considered as late Eocene or early Oligocene in age. It is distinctly more advanced than any of the wealth of forms known from the Bridger formation, or even most of those known from the Uinta beds. The dentition is very progressive and approaches the Chadron forms in the reduction of the incisors and in the molarization of the premolars, but does not show the facial shortening and the crowding of the incisors and premolars usually characterizing the Oligocene genera.

From this it is evident that either a titanothere having a more advanced type of dentition existed in Mississippi contemporaneously with a number of less progressive types, as known from the Bridger beds of Wyoming and currently regarded as middle Eocene, or the age assignments made to portions of the two stratigraphic sequences are not in harmony. It seems more probable that the age assignment made to one or the other sequence is in error and that the Uintan, or possibly the Duchesnean, is to be correlated with the Lisbon portion of the Claiborne.

As to the part of the Eocene represented by the correlated portions of the two sequences, the evidence to be derived from the land mammals themselves is not particularly satisfactory inasmuch as no direct correlation is permitted between North America and Europe during middle and upper Eocene time. As Osborn has shown, after Sparnacian or possibly Ypresian time, and until the Sannoisian of Europe, the terrestrial mammalian faunas are very distinct. The Sparnacian or lower Eocene of Europe has a fauna comparable to that of the Wasatch of North America, and the lower Oligocene Sannoisian is about equivalent to our Chadron. However, as a limiting factor in the foregoing consideration we know that the Jackson formation, stratigraphically younger than the Lisbon, has been shown by Kellogg[3] on the evidence of the archaeocete fauna to be Bartonian upper Eocene in age and is correlated in part directly with the Barton Clays of England, and in part with the Qasr-el-Sagha stage of the Fayum, Egypt. The Lisbon formation might conceivably

[3] Kellogg, Remington, Carnegie Inst. Washington Publ. 482, p. 272, 1936.

be included also in the upper Eocene, but representing a lower stage than the Jackson; however, Dr. Gardner informs us that the Lisbon appears most closely associated in time with the Lutetian middle Eocene of the Paris Basin. In any case the Uintan stage should on the basis of the foregoing evidence apparently be regarded as not younger than lowermost Bartonian and possibly as old as Lutetian. Moreover, the possibility that a more direct correlation is to be made between the Lisbon and Duchesne River beds rather than between Lisbon and Uinta cannot be disregarded, but unfortunately our knowledge of Duchesnean titanotheres is far from complete and is limited at present to a few forms allocated to the genus *Teleodus*.

NOTIOTITANOPS,[4] new genus

Generic characters.—Facial portion of skull elongate. Teeth uncrowded. Incisors with noncingulate, globular crown, reduced to two pairs, transversely arranged, and with a marked cleft between median pair. Canines rounded. Marked diastema between canines and premolars. Premolars very progressive. P^1 with prominent deuterocone portion. Lingual cingulum weak or incomplete on upper premolars and not present on molars. Metaconid of P_3 elevated and lingual as in P_4. Lower molars and preserved premolars with well-developed metacristid.

Genotype.—*Notiotitanops mississippiensis,* new species.

NOTIOTITANOPS MISSISSIPPIENSIS,[5] new species

Type.—Basal portion of skull with complete dentition, except for three incisors, and portions of both rami of the mandible with P_3 to M_3 represented, U.S.N.M. No. 16646.

Horizon and locality.—Lisbon formation, about 2½ miles south of Quitman, Clarke County, Miss.

Specific characters.—Size of skull and length of dental series comparable to that of *Diplacodon progressum* Peterson. Specific characters not otherwise distinguished from generic.

Description of skull.—The skull of *Notiotitanops mississippiensis* is about the size of that of *Diplacodon progressum* Peterson[6] from the upper part of Uinta "C," larger than that of *Teleodus uintensis* Peterson[7] from the Duchesne River beds, as indicated by the para-

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[4] νότιος, southern; τιτάν, titan; 'οψ, aspect.

[5] From the State of Mississippi.

[6] Peterson, O. A., Ann. Carnegie Mus., vol. 22, pp. 351-355, 1934.

[7] Peterson, O. A., ibid., vol. 20, pp. 307-312, 1931.

type, and apparently smaller than material representing species of *Protitanotherium.* The facial portion of the skull is moderately long as in such forms as *Diplacodon, Eotitanotherium,* and *Protitanotherium,* but not nearly so prolonged as in *Dolichorhinus.* Unfortunately, the top of the skull was eroded away so that no evidence remains of the presence or absence of horns. The palate exhibits a long diastema between the canine and P^1, and the incisive border of the premaxillae is directed transversely between the canines, not rounded or projecting forward as in the known Uinta titanotheres. In this respect *Notiotitanops* more nearly resembles *Teleodus.* The notch between the nasal and premaxilla extends posteriorly to a point near the infraorbital foramen and approximately above the posterior margin of P^2. The anterior opening of the infraorbital foramen is above most of P^3 and possibly the anterior portion of P^4. The anterior margin of the orbit is not complete, but it apparently extended forward to a position about over the middle or anterior portion of M^1. The lowest point of the orbital margin of the jugal is over the anterior portion of M^2.

Basicranium.—The basicranial portion of the skull is rather well preserved, and as is the case with most of the skull, as far as complete, appears to be entirely uncrushed. The squamosal on the right side is lacking but the basal portion of the cranium is nearly entire on the left side, except for a part of the zygomatic process of the squamosal. The cranial portion of the skull, as is the case with the facial portion, shows no significant shortening. In fact, the distance between the last molar and the postglenoid process is actually as great as in a much larger Chadron skull identified as *Brontotherium curtum.* The elongate posterior narial opening has nearly parallel sides, and has preserved the septum dividing it beyond the entire length and most of the depth of this opening. The posterior margin of the pterygoid forms a crest with the alisphenoid which originates with the posterior and ventral margin of the foramen ovale. In *Notiotitanops* this crest descends more abruptly from the region of the foramen ovale than in such forms as *Brontotherium,* somewhat as indicated in Peterson's [8] illustration of the type of *Diplacodon progressum.* However, the foramen ovale and the posterior opening of the alisphenoid canal are much more widely separated than indicated in Peterson's illustration. The foramina penetrating the alisphenoid bones are relatively large and rather well spaced as compared with these structures in either the earlier Bridger forms or

[8] Peterson, O. A., ibid., vol. 22, pl. 27, 1934.

the later Chadron types. The alisphenoid canal is directed more anteroposteriorly than in *Brontotherium*, where the foramen rotundum with the anterior opening of the alisphenoid canal is more dorsally placed with respect to the posterior opening of the canal. The posterior opening of the alisphenoid canal faces laterally, rather than ventrally as in the Chadron material.

The basioccipital and basisphenoidal portion is nearly triangular in section, dorsally broad and noticeably deep through the median portion as compared with such forms as *Palaeosyops*. The postglenoid process is broad, very elongate, and with a noticeable excavation on its anterolateral face for the entire length. The paroccipital process extends downward to an even greater extent than the postglenoid process. A conspicuous opening, apparently the mastoid foramen, is seen just above the outer margin of the paroccipital process, presumably about at the contact between the periotic and exoccipital bones, and appears to have conducted a part of the venous system of the occipital region, tied in with that which emerged from the postglenoid foramen.

The false external auditory meatus is deeply recessed above the basicranial surface as compared with the more shallow and open groove that represents this structure in the Bridger titanotheres. The rather long canal appears to be embedded entirely in the squamosal, but the extent to which the mastoid portion of the periotic is excluded from a position adjacent to the postglenoid process below cannot be certainly determined. The massive structure nearly or quite closing the canal ventrally is at least for the most part the posttympanic process of the squamosal. The closure is completed medially by a long, flat, wedgelike extension of the tympanic, occupying the rather deep and very narrow cleft between the postglenoid process and the posttympanic as far laterally as the postglenoid foramen. In the Chadron forms the posttympanic process is usually better developed ventrally, and possibly laterally, and appears to make a broader, deeper union with the postglenoid process.

Tympanic.—The tympanic is not completely preserved, but as far as represented it is securely attached to the periotic in the two positions about corresponding to the legs of the annulus, and by a lateral flange or portion of the audital tube to the squamosal. The posterior pedicle joins the periotic anterior to the lateral extremity of the facial canal, just posterior to the position of the tympanic membrane. The anterior pedicle joins approximately above the origin of the styliform process of the tympanic, just anterior to the position of the tympanic membrane. It is uncertain just how far medially the tympanic was ossified, as the margin of the bone is damaged. It may not have been complete across the entire width of the petrosal. A prominent flange of the tympanic, however, extends laterally in the narrow cleft between the postglenoid and posttympanic processes completing the closure of the false external auditory meatus below. Medially this lateral flange of the tympanic also covers a small part of the posterior wall of the audital canal, and a lip of it extends a very short distance up the anterior wall close to the medial margin of the root of the postglenoid process. The osseous audital tube is open anteriorly for a short space medial to the inner margin of the postglenoid process.

A rather large but incomplete tympanohyal is preserved in a recess of the posterolateral portion of the tympanic, anterolateral to the inner margin of the paroccipital process, probably adjacent to both the exoccipital and the mastoid. The stylomastoid foramen occurs between the posteroexternal portion of the tympanohyal and the mastoid portion of the periotic. A short distance medial to this position and still adjacent to the tympanohyal a second foramen is visible in the ventral view. This, however, converges with the stylomastoid foramen dorsally and may join it.

Petrosal.—The petrous portion of the periotic is complete except for a small segment of the very thin ventromedial margin. This element is a rather large wedgelike mass tapering ventromedially and with its thick base merging dorsolaterally with the spongy mastoid portion. In the dorsomedial view the rather large internal auditory meatus is seen to open on the medial margin of the bone much as in the Chadron forms, but with the dorsal margin forming a much more compressed anteroposterior ridge than in the larger petrosals of *Brontotherium* and *Menodus*. Also, as in the Chadron forms, the medial margin exhibits a channel about the width of the foramen extending posteriorly from the meatus; this, however, is not so broad dorsoventrally as in *Menodus,* but appears fully as long anteroposteriorly. In *Palaeosyops* the internal auditory meatus is distinctly removed from the somewhat thickened ventromedial margin of the petrosal. The posterior margin of the opening is complete and the shallow channel issuing from the opening is directed anteromedially.

The surface above the internal auditory meatus, regarded as the floccular fossa, is moderately extensive but not deeply excavated. Anterior to this the angle which is interpreted as marking the separation between the cerebral and cerebellar portions of the brain is not particularly acute, and there is no indication of the bony ridge that in more modern mammals rises to join the tentorial plate. In *Palaeosyops* the petrosal shows no indication of a juncture of the cerebrum and cerebellum.

Posterior to the floccular fossa the exact position of the aquaeductus vestibuli and the aquaeductus cochleae cannot be certainly determined because of the spongy character of the bone at the transition to the mastoid portion, but the aquaeductus vestibuli appears to be just beyond the posterodorsal extent of the floccular fossa, and the aquaeductus cochleae at the posteroventral margin of the fossa.

In the ventral aspect the petrosal exhibits a marked promontorium, much more prominent and inflated than in *Palaeosyops* but not so massive and anteroposteriorly expanded as in the Chadron material observed. The facial canal at its lateral extremity rises from the stylomastoid foramen to the petrosal at a position posterolateral to the fenestra rotunda, forms a relatively deep impression in the petrosal lateral to the fenestra rotunda, passes forward somewhat shallower lateral to the fenestra ovalis, and then extends anteromedially to the anterior margin, at which point it joins a foramen that connects with the internal auditory meatus. At this position the unclosed hiatus facialis coincides with the geniculum of the facial nerve. At no place in the course of the facial canal or sulcus is it completely enclosed by bone between the position of the geniculum and its ventrolateral extremity in the petrosal. A marked approach toward closure, however, is made at the positions where the tympanic is attached to the petrosal, namely at its stylomastoid extremity, where bone nearly crosses the sulcus lateral to the fenestra rotunda, and at the forward extremity, anterior to the fenestra ovalis. In *Palaeosyops* it is interesting to note that the facial sulcus is much shallower, and the fenestra ovalis, which in life is covered by the stapes, faces much more ventrally, possibly suggesting a more nearly horizontal tympanic annulus. In the Chadron material examined the facial canal appears to be closed completely in the positions at which an approach to closure is made in *Notiotitanops;* however, as in that form, the canal is open entirely across the aperture lateral to the fenestra ovalis.

The tensor tympani muscle in *Notiotitanops* presumably originated in a moderately large, much recurved fossa lateral to the extended crista facialis, somewhat lateral and anterodorsal to the fenestra ovalis. The stapedial muscle may have originated in some part of the same fossa. A very small pit just posterior to the fossa may have been the position occupied by the crus breve of the incus. The fossa believed to be that of the tensor tympani is appreciably larger in a specimen of *Menodus.* I am unable to delineate it in *Palaeosyops,* unless it be a very shallow depression on the side of the promontorium posteromedial to the facial sulcus.

Upper dentition.—The dentition of *Notiotitanops mississippiensis* is very progressive for Eocene titanotheres. The incisors are reduced to two pairs, uncrowded, and the preserved lateral incisor is not of the piercing type but exhibits a globular crown without evidence of a ridge or shelflike cingulum so characteristic of the Eocene forms having teeth otherwise in an equivalent stage of wear. This type of incisor is noted in the Duchesne River and Sespe *Teleodus* and in most of the Chadron titanotheres.

The canine is moderately large, rounded, and markedly curved in the crown portion. The anterior surface of the canine is forward of the anterior margin of the premaxilla, a position not occurring in such forms as *Dolichorhinus, Eotitanotherium* or *Diplacodon,* but observed in *Teleodus* and many Chadron specimens.

The premolars are advanced in the degree to which they have become molariform, about equivalent in this respect to those in *Diplacodon* and *Eotitanotherium,* and certainly much advanced over the development reached in *Dolichorhinus, Metarhinus,* etc. P^1 is an anteroposteriorly elongate tooth but exhibits a rather well-developed, posteriorly placed deuterocone. Also, the tritocone is distinct and about as well developed as the primary cusp. This tooth appears to be in as advanced a stage of development as that reached in the most progressive Uintan titanotheres and as that in some of the Chadron material, but without the anteroposterior compression characterizing the later dentitions. P^2 and P^3 have a full, nearly molariform outline. The lingual portion of P^2 is anteroposteriorly broad, with but little indication of a cingulum, and the elongate deuterocone crest shows a slight indication of a separate tetartocone. The cingulum is weak internally on P^3 and slightly better developed and more nearly continuous on P^4, although it is absent from the molars. The lingual crest on P^3 and P^4 is more clearly divided into a deuterocone and lesser tetartocone, but this portion of these teeth, though somewhat worn, appears much inflated and the separation of the tetartocone is not sharp and deep in contrast to the separation of the hypocone in the molars. The mesostyle is fairly well developed on P^4, much weaker or slight on P^3, and not seen on P^2. This style shows a nearly uniform increase in prominence from P^3 to M^3.

The upper molars are essentially like those of the Uintan or even Chadron titanotheres, but certain structural differences were noted. In comparison with those of *Diplacodon* they are distinctly wider transversely; also, M^3, which is larger and transversely wider than M^2, has a well-developed hypocone, and the buccal and lingual walls of this tooth do not converge posteriorly so markedly as in *Dipla-*

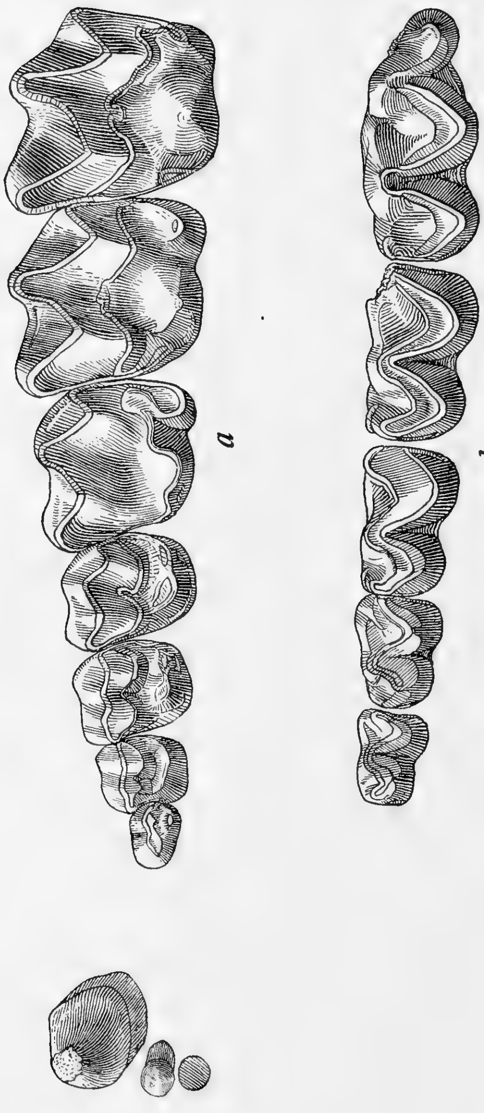


Fig. 1.—*Notiotitanops mississippiensis*, new genus and species. Left upper and lower dentitions, U.S.N.M. No. 16646, type specimen, occlusal views. $\times \frac{1}{2}$. *a*, I, C., and P^1 to M^3; *b*, P_3 to M_3. Lisbon Eocene, Mississippi. Drawing by Sydney Prentice.

codon. The hypocone is smaller than the protocone in the various molars but is distinctly more lingual in position than in *Diplacodon.* The appearance of the molars in the region of the hypocone is suggestive of some of the much larger Chadron brontotheres.

Mandible and lower dentition.—The lower jaws of *Notiotitanops mississippiensis* are rather incomplete but appear relatively robust, and the symphysis is seen to extend posteriorly to a point below P_4. On the right ramus a mental foramen is situated below the posterior root of P_3 and an anterior branch of this canal appears below a position which would be occupied by the posterior root of P_2 if this tooth were present. On the left ramus a mental foramen is seen below the anterior root of P_3. Both rami are incomplete anterior to the third premolar, and only P_3 to M_3 are known. M_3 is missing from the right ramus.

The lower cheek teeth increase in size uniformly from P_3 to M_3 and the two premolars appear to be markedly molariform, but with a somewhat less distinct notch between the paraconid and metaconid than in the molars. The paraconid and entoconid on P_3 and P_4 approach the development seen in the molars, a distinct advance over *Dolichorhinus,* etc. In P_3 the metaconid is elevated and set lingually much as in P_4 and the molars, *Notiotitanops* being more progressive in this respect than *Protitanotherium.* The preserved premolars and molars show a rather well-developed metacristid extending posteriorly to a notch which is very near the entoconid, a significantly advanced condition.

Comparisons.—*Notiotitanops mississippiensis* is seen to be most nearly comparable to *Diplacodon* and related *Protitanotherium* and *Eotitanotherium* of the Uinta in certain respects and to *Teleodus* of the Duchesne River stage in others. It resembles *Diplacodon* in size and facial length, including the diastema between the canine and cheek teeth of the upper dentition, and in the progressiveness of the premolars. It differs from *Diplacodon* most noticeably in the reduction of the incisors and in the globular, noncingulate character of these as indicated by the one that is preserved. Moreover, the molars are broader transversely, not so convergent posteriorly, and with a more lingually placed hypocone. The form resembles *Teleodus* in the reduction and form of the incisors, in the abbreviation of the premaxillae anterior to the canines, as well as in the progressiveness of the premolars. It differs from *Teleodus* in the greater length of the facial portion, including the presence as well as the marked length of the postcanine diastema. Moreover, *Notiotitanops* almost certainly did not have the reduced number of lower premolars indicated for *Teleodus.*

It is important to note that the tympanic and petrosal as well as the dentition show a very marked advance over these elements, as known or interpreted, of the Bridger titanotheres, heretofore regarded as middle Eocene.

It is further observed that in a comparison with titanothere remains as described from the Pacific Coast region, *Notiotitanops* shows a development more advanced than that indicated by the *Metarhinus* material[9] from the Poway conglomerate, which in turn has been correlated with the marine Tejon formation.[10] This would suggest that the Tejon stage as represented by the Poway conglomerate is not younger and possibly is older than the horizon in the Lisbon that produced *Notiotitanops.*

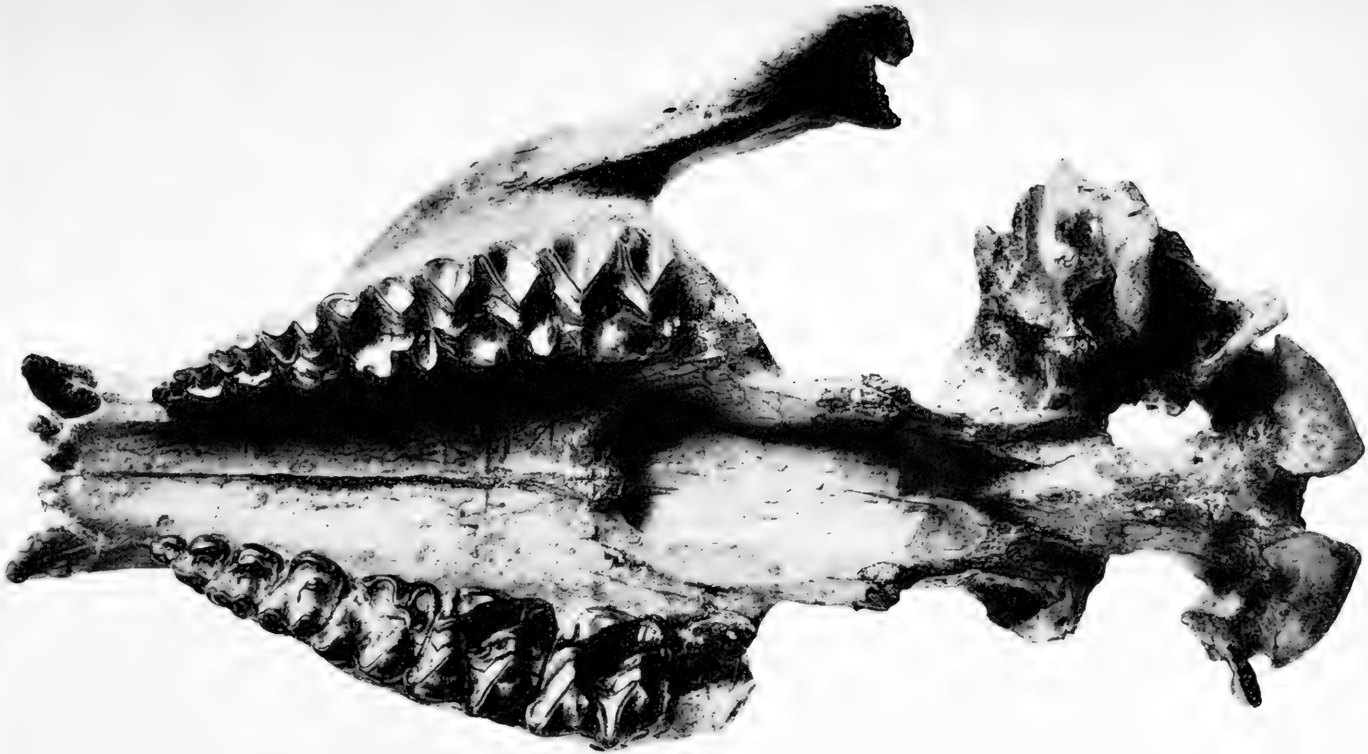
Measurements (in millimeters) of skull, mandible, and dentition of Notiotitanops mississippiensis, *U.S.N.M. No. 16646*

Greatest length from anterior margin of premaxillae to posterior margin of occipital condyles	560
Distance from anterior margin of premaxillae to posterior narial aperture	252
Distance from anterior margin of posterior narial aperture to posterior margin of pterygoids above the hamular processes	120
Distance between M^3 and the apex of the postglenoid process	191
Distance between median incisor alveoli	12.1
Distance across alveoli of two incisors on one side	16.2
Greatest width across canines at cingula	91.6
Width between canines at alveoli	42.7
Least width at constriction posterior to canines	82.5
Width of palate between anterointernal portions of second premolars	50.5
Width of palate between anterointernal portions of second molars	84.8
Width of posterior narial opening ventrally and anterior to the pterygoids	47
Distance from median plane to outer margin of postglenoid process	133
Distance across paroccipital processes near apices	167
Width across occipital condyles	143
Length of upper dentition from anterior margin of canine at cingulum to posteroexternal angle of M^3	288
Distance between alveoli of canine and P^1	28
Length of cheek tooth series, P^1 to posteroexternal angle of M^3	229
Length of premolar series, P^1 to P^4 inclusive	90.7
Length of molar series, M^1 to M^3 inclusive and externally	147
Lateral incisor—anteroposterior diameter: transverse diameter	10.5 : 8.8
Canine—anteroposterior diameter at cingulum: transverse diameter	27 : 24

[9] Stock, Chester, Proc. Acad. Nat. Sci., vol. 23, No. 2, pp. 48-53, 1937.

[10] Hanna, M. A., Univ. California Publ., Bull. Dep. Geol. Sci., vol. 16, pp. 256-263, 1927.

P^1—anteroposterior diameter: greatest transverse diameter	17.2 : 13.2
P^3—anteroposterior diameter including parastyle: transverse diameter	26.2 : 30.9
M^1—anteroposterior diameter including parastyle: transverse diameter across mesostyle and protocone	43.5 : 42
M^3—anteroposterior diameter externally including parastyle: transverse diameter across mesostyle and protocone	58.0 : 56.5
Depth of lower jaw below point between P_4 and M_1 on lingual side	90
Depth of lower jaw below occlusal surface of M_2 measured from valley immediately lingual to hypoconid	112
Length of preserved lower dentition, P_3 to M_3 inclusive	210
Length of lower molar series, M_1 to M_3 inclusive	155
P_3—anteroposterior diameter: transverse diameter	25.6 : 19.2
M_1—anteroposterior diameter: transverse diameter	39.0 : 26.7
M_3—anteroposterior diameter: transverse diameter	69.2 : 31



NOTIOTITANOPS MISSISSIPPIENSIS, NEW GENUS AND SPECIES

Ventral view of skull, U.S.N.M. No. 16646, type specimen approximately one-third natural size. Lisbon Eocene, Mississippi.

NOTIOTITANOPS MISSISSIPPIENSIS, NEW GENUS AND SPECIES

Lateral view of skull and left ramus of mandible, U.S.N.M. No. 16646, type specimen, approximately one-third natural size. Lisbon Eocene, Mississippi.

NOTIOTITANOPS MISSISSIPPIENSIS, NEW GENUS AND SPECIES

Dorsal view of both rami of the mandible, U.S.N.M. No. 16646, type specimen, approximately one-third natural size. Lisbon Eocene, Mississippi.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 101, NUMBER 14

TWO NEW FOSSIL BIRDS FROM THE OLIGOCENE OF SOUTH DAKOTA

BY
ALEXANDER WETMORE
Assistant Secretary, Smithsonian Institution

(PUBLICATION 3680)

CITY OF WASHINGTON
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TWO NEW FOSSIL BIRDS FROM THE OLIGOCENE OF SOUTH DAKOTA

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In the season of 1940 a joint expedition of the National Geographic Society and the South Dakota State School of Mines made detailed explorations for vertebrate fossils in the Oligocene deposits found in Washington County, S. Dak., in the Pine Ridge Indian Reservation. The party was under the leadership of Dr. James P. Connolly, with Dr. James D. Bump in charge of the exploration and collecting, assisted by Prof. Arthur C. McIntosh, assistant professor of biology, with Mahlon Binder, Thomas Blackstone, Blair Molander, Curtis Graversen, and Merle Crew as technical assistants, the latter being students carrying major studies in geology in the State School of Mines. Desmond Yetter, another student, was camp assistant. The results of the work were exceptionally fruitful, and included certain bones of birds which are here described.

According to data furnished by Dr. Connolly and Dr. Bump the bird material was collected in a small area including the west half of T. 41 N., R. 42 W., and the eastern tier of sections in T 41 N., R. 43 W. The locality is about 25 miles southeast of Scenic, and about 6 miles east of Rockyford. The bird material comes from the Brule formation of the Oligocene, having been obtained in the areas and deposits of Protoceras Channel sandstone found in the Leptauchenia clays. The specimens serve as an important contribution to our knowledge of the bird life of the North American Oligocene, a field in which until very recently comparatively little has been known.

The field work was financed by a grant from the National Geographic Society in connection with the program of scientific research of the Society.

Drawings illustrating this report have been prepared by Sydney Prentice.

Family ARAMIDAE. Limpkins

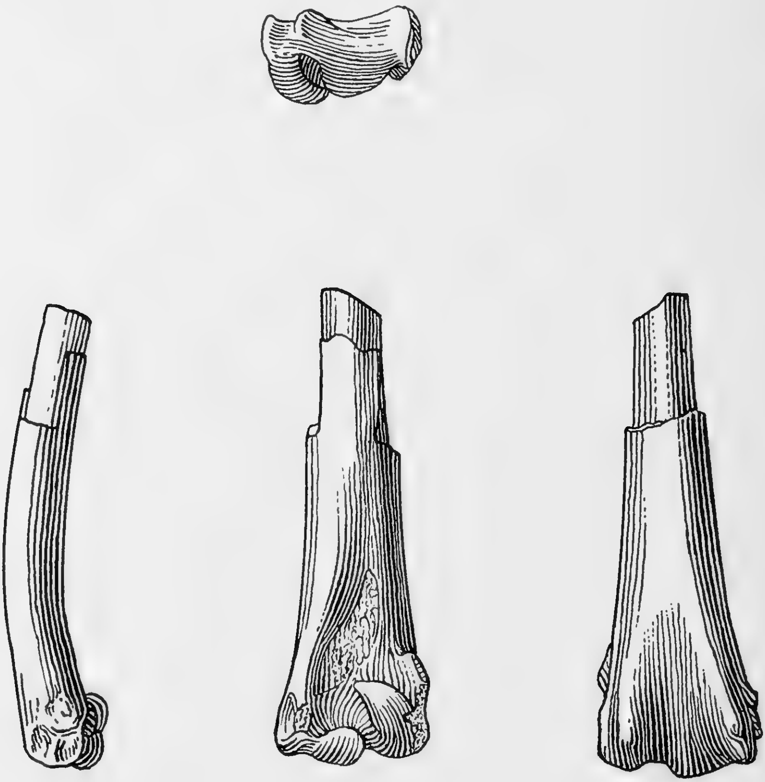
GNOTORNIS ARAMIELLUS, new genus and species

Characters.—Distal end of humerus (figs. 1-4) similar to that of modern *Aramus scolopaceus* (Gmelin),[1] but entepicondylar area

[1] *Ardea scolopacea* Gmelin, Syst. Nat., vol. 1, pt. 2, 1789, p. 647.

projecting only slightly laterally; ectepicondylar area relatively larger.

Description.—Type, distal end of left humerus, Cat. No. 40158, Museum of the South Dakota State School of Mines, Department of Geology and Mineralogy, from the Protoceras Channel sandstone of the Leptauchenia clays, Brule beds, Upper White River Oligocene,



FIGS. 1-4.—Four views of the type specimen of *Gnotornis aramiellus*, twice natural size.

25 miles southeast of Scenic and 6 miles east of Rockyford, Washington County, S. Dak., collected by the National Geographic Society–South Dakota State School of Mines Paleontological Expedition of 1940.

Distal section of shaft relatively strong, decidedly flattened, curved slightly forward at the lower end, and only slightly expanded to support the distal part of the bone, in cross section a much flattened ellipse; brachial depression of good size and distinctly impressed;

radial trochlea compressed, elevated, with upper margin undercut, being a relatively narrow plate, somewhat narrower toward its upper, elevated, free point where it has a slight inward flexure; ulnar trochlea relatively small, rounded; olecranal depression broad, shallow and open; ectepicondylar process (imperfect) projecting slightly outward; entepicondyle projecting little laterally beyond level of side of shaft, when viewed from the side showing a rounded distal margin; attachment for anterior ligament relatively small and flat, placed on a raised ridge. Bone light grayish brown.

Measurements.—Transverse width across trochlea 10.4, least transverse breadth of shaft 5.7, thickness of shaft at this point 4.2 mm.

Remarks.—This species makes the third of its family known in the fossil state, the other two being *Badistornis aramus* Wetmore from the Brule beds of the Oligocene of South Dakota, and *Aramornis longurio* Wetmore from the early Middle Miocene of Nebraska. The two just mentioned are known from the lower limb only so that comparison with them of *Gnotornis aramiellus* described from part of the humerus is difficult. In an earlier account [2] I have stated that *Aramornis* is more like modern *Aramus* and that *Badistornis*, while belonging with the limpkins (family Aramidae), offers some approach to the cranes (family Gruidae), seeming to point to a line of common origin between the two families mentioned.

The partial humerus that forms the type of *Gnotornis aramiellus* is distinct from both Gruidae and other Aramidae in the restriction of the entepicondylar area, seeming in this to stand so much apart as to make it necessary to place it in a distinct genus. It is notable for its small dimensions, having been apparently only about one-third the size of other known limpkins, living and fossil. It is a notable find therefore among fossil birds, being of a group in its family of which hitherto there has been no hint.

Family BATHORNITHIDAE. Bathornithes

BATHORNIS GEOGRAPHICUS, new species

Characters.—Metatarsus (figs. 5-9) generally similar to that of *Bathornis veredus* Wetmore [3] but with middle trochlea definitely stronger and heavier; bladelike posterior projection of the inner trochlea with lower edge of the distal margin nearly on a line with the

[2] Wetmore, A., Journ. Morph., vol. 66, 1940, pp. 33-34.

[3] *Bathornis veredus* Wetmore, Proc. Colorado Mus. Nat. Hist., vol. 7, No. 2, July 15, 1927, p. 11, figs. 19-24 (Chadron deposits of the Oligocene, Horsetail Creek, Weld County, Colo.).

distal margin of the body of the trochlea, instead of being elevated to project near the middle.

Figs. 5-9.—Five views of the type specimen of *Bathornis geographicus*, partly restored, natural size.

Description.—Type, partly complete left tarsometatarsus, Cat. No. 4030, Museum of the South Dakota State School of Mines, Department of Geology and Mineralogy, from the Protoceras Channel sandstone of the Leptauchenia clays, Brule beds, Upper White River Oligocene, 25 miles southeast of Scenic and 6 miles east of Rockyford, Washington County, S. Dak., collected by the National Geographic Society–South Dakota State School of Mines Paleontological Expedition of 1940.

Proximal end of bone with a high intercondylar tubercle that rises from the anterior margin and slopes posteriorly, separating the two glenoid facets, an indistinct groove running transversely across the upper surface at its highest point; both glenoid facets elliptical in form with raised margins; talon with base broad; outer head indicated by a slight ridge; inner head strong and heavy, with indication of a single tendinal perforation, merging posteriorly through a thin, constricted ridge with the shaft near its upper third; posterior face of shaft with a shallow groove delimited by sharply angular edges; shaft at the proximal end below the head with a distinct depression which continues down in a broad anterior groove; shaft strong in spite of its length, flattened and expanded at the lower end; middle trochlea very strong and heavy, with a pronounced groove around its free margin; inner trochlea with inner and outer faces deeply concave, a faint groove around the free margin, and its platelike process having the distal margin on a line with the distal edge of the trochlea; outer trochlea fragmentary, showing only the posterior section, its external margin produced slightly. Bone light grayish brown in color.

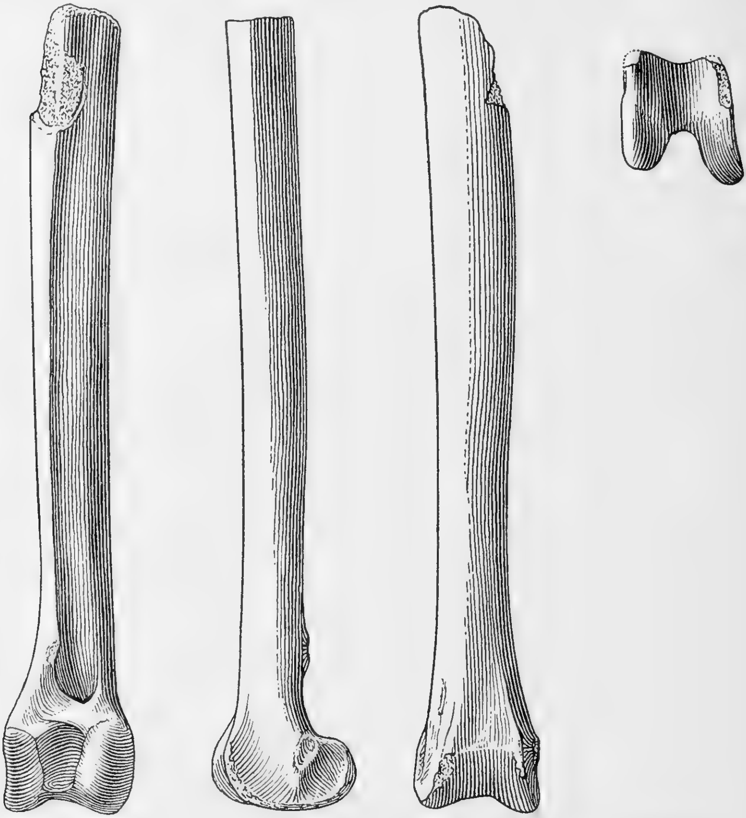
Measurements.—Total length (approximate) 120, transverse diameter of head 20.4, least transverse diameter of shaft 9.0, transverse diameter across trochlea (approximate) 21.0 mm.

Remarks.—This bird evidently is representative of *Bathornis veredus* of the Chadron beds, differing from that species in the material at hand so little as to make it appear certain that it is in the line of direct descent from the older form. The upper part of the metatarsus is unknown at present in *B. veredus,* but it has been interesting in this connection to compare the smaller *B. celeripes* of which abundant material has been found. The differences from *celeripes* shown by *geographicus* are those of decidedly larger size and more robust form, the two species having the metatarsus in outline closely similar. There is no mistaking their affinity when the two are examined side by side, the contours being almost identical.

A left tibiotarsus (figs. 10-13) lacking the head, with the shaft somewhat damaged, was found associated with the metatarsus and belongs evidently to the same individual. It is cataloged under the same number (4030). It agrees in general with the tibiotarsus in the collection of Princeton University that I have identified as

Bathornis veredus,[4] but has the inner condyle relatively larger and thinner and the intercondylar groove larger. The bone itself is very slightly smaller, measuring 16.5 mm. transversely across the condyles as against 18 mm. in the Princeton specimen.

The specific name *geographicus* is given to commemorate the interest of the National Geographic Society in the explorations that led to the discovery of this interesting bird. The Bathornithes form a



FIGS. 10-13.—Four views of the tibiotarsus of *Bathornis geographicus*, partly restored, natural size.

group, now wholly extinct, that seemingly was found throughout the Oligocene. The four known species are as follows:

Bathornis veredus Wetmore, Chadron; known from Weld County, Colo., near Crawford, Nebr., and from Pennington County, S. Dak.

Bathornis celeripes Wetmore, Brule; known from near Torrington, Wyo., and 12 miles northwest of Crawford, Nebr.

Bathornis cursor Wetmore, Brule; near Torrington, Wyo.

Bathornis geographicus Wetmore, Brule; from Washington County, S. Dak.

[4] Condor, 1937, pp. 256-257.

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FIFTH CONTRIBUTION TO NOMENCLATURE OF CAMBRIAN FOSSILS

BY
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(Publication 3682)

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This is the fifth in the series of papers designed to care for changes necessary in the names of Cambrian fossils. When the fourth[1] paper was published it was hoped that further changes would be so few and so obvious that they could be incorporated in the Cambrian bibliographic summary, and would not be required to appear first in a separate paper. But even now it is impossible to gather all of the known errors for rectification in this paper. For example, correction of some errors must await the opportunity to examine the specimens because the published illustrations, obviously showing incorrect generic determinations, are too poor to permit a proper understanding of the fossil. In the other instances where new generic designations are clearly indicated, erection of new genera should await the publication of a paper with illustrations, because better-preserved specimens are in hand, or undescribed species portray the generic characteristics more fully and should therefore be chosen as the genotypes. And finally, still other incorrectly placed species cannot be reassigned until better-preserved specimens are found.

Certain changes contained in this paper have arisen from revision of genera during the description of new species. It is common experience that when new species are added to a genus, regardless of whether it originally was monotypic or contained many species, its concept changes. As further species are added, it often becomes clear that earlier assignments were made on family rather than generic characteristics. For this reason many genera need revision from time to time.

The second source of changes lies in the erroneous interpretations contained in certain recent papers describing Cambrian fossils. In

[1] Resser, Charles E., Nomenclature of some Cambrian trilobites, Smithsonian Misc. Coll., vol. 93, No. 5, Feb. 14, 1935; Second contribution to nomenclature of Cambrian trilobites, ibid., vol. 95, No. 4, Apr. 1, 1936; Third contribution to nomenclature of Cambrian trilobites, ibid., vol. 95, No. 22, Apr. 5, 1937; Fourth contribution to nomenclature of Cambrian fossils, ibid., vol. 97, No. 10, Dec. 17, 1938.

late years a great many papers dealing with Cambrian stratigraphy and paleontology have appeared, and more persons are writing in this field. Naturally many important facts have been brought to light and a considerable number of new species described. Many of these papers are excellent, but in some the quality of work leaves much to be desired, and for years to come it will be necessary to rectify errors and misinterpretations, many of which could have been avoided.

Numerous species from Asia are included in this paper. Studies during the past several years, involving Asiatic species, brought to light the degree to which workers dealing with Asiatic Cambrian fossils have been handicapped by unavailability of comparative material. Also, it must be remembered that nearly all work was in virgin territory. Even now only a beginning can be made in the revision of Asiatic Cambrian nomenclature. Many hundreds of new species are in hand, and they will, without doubt, throw much light on the significance of described genera and bring out many new ones. The purpose of making some of the needed changes affecting Asiatic species at this time is to attempt to forestall other mistakes by calling attention to existing ones. Only those changes have been made which could be based on specimens available to me, or which were perfectly obvious from published illustrations.

Certain nomenclatural changes for brachiopods were included in the first draft of this manuscript. However, it was soon discovered that several hundred changes and restrictions of species are necessary, which it is hoped may be done by someone else.

NOTE ON STATUS OF CLASSIFICATION OF TRILOBITES

Twenty-five years ago it was generally believed that Cambrian trilobite classification was fairly satisfactory and complete, except for a few unplaced genera. However, those who were familiar with the national collections at that time, knew that only a small proportion of the species on hand had been described. Furthermore, those then familiar with the Cambrian system also knew that many areas of outcrop had not yet been explored and were sure to yield large collections.

Ulrich discussed this question in 1929, and the arguments he then used are still pertinent in spite of the greatly increased number of species since described. Today there are still too many undescribed species on hand to warrant the erection of a classification intended to embrace the whole of the class.

In recent years several more or less general classifications have been attempted. In 1927 Poulsen discussed Beecher's orders and briefly considered the major trilobite families, particularly with reference to the Cambrian genera. At that time he changed Swinnerton's (1915) suborder Mesonacida (Olenellida) to an order, removing this group from the Opisthoparia. He then suggested two orders to embrace the remaining trilobite genera, the Integricephalida and the Suturicephalida, the latter possibly to include Beecher's Opisthoparia and Proparia as suborders. At the same time Poulsen set up some new trilobite families, subsequent modification of which resulted from two causes: First, the stratigraphic position of some of Poulsen's material could not then be determined accurately, and consequently he was unable to tell the relative ages of the genera; second, addition of numerous species—often with better-preserved material—has altered and enlarged the concept of several genera; with the result that some of the families had to be subdivided. Time will tell whether it is going to be desirable to use Poulsen's classification further.

Lorenz (1906) based a partial classification on porosity and granulosity of the test, characters which appear to have no value in this connection.

Swinnerton (1915) reviewed and criticized the classifications of Gürich (1907) and Jaekel (1909), and gave one of his own. Gürich based his classification on the number of free segments and size of the pygidium, which, as Swinnerton states, are progressive characters and hence valueless for this purpose. He also called attention to the fact that Jaekel removed the agnostids from the trilobites because of their few segments. Swinnerton then proposed another grouping, in which he recognized several suborders within Beecher's Opisthoparia and Proparia. Subsequent authors have not followed Swinnerton, although it appears that his suggestions have merit.

In 1935 Kobayashi reviewed previous classifications, adopted a new one, and classified chiefly the Cambrian genera. He did not carry his work to completion, hence it is not possible to determine precisely what orders he had in mind. For the Cambrian genera mainly, he recognized five suborders, and set up numerous additional families, many of which must be revised, because he depended too much on similarity in appearance as expressing relationship. Moreover, he frequently failed to give due consideration to stratigraphic position, or relative age of genera. Naturally, many of the new families are valid and serve a useful purpose, but the work as a whole evidences the haste with which it was done.

Since Jaekel stressed the difference between the agnostids and trilobites, most authors have been inclined to follow him. In 1934

Howell and Resser proposed the recognition of the agnostids as an order, in which they were followed by Kobayashi (1935, 1939). In the latter year Kobayashi attempted a classification of the entire group of agnostids. Unfortunately it is necessary to call attention to the fact that much of Kobayashi's 1939 paper was copied, without permission, from the manuscript being prepared by Howell and myself. It, therefore, reflects our views up to the time when the particular portions of the manuscript were written, but in many instances we no longer hold strictly to those views.

It is my idea that the agnostids constitute a subclass, holding equal rank with Trilobita and other recognized subclasses of the Crustacea. I also consider the Olenellida as an order, but have no final opinion of the value of the remaining Beecher orders.

Thanks are due Prof. G. M. Ehlers, University of Michigan, for loan of Rominger's types. The attempt was made to ascertain every type specimen among the material left by Rominger in an unmarked condition. Some figures are no doubt composite, but others could be recognized, as discussed on subsequent pages.

TRILOBITA

ALOKISTOCARE Lorenz, 1906

Alokistocare brighamense, new species

Alokistocare laticaudum Resser (part), Smithsonian Misc. Coll., vol. 97, No. 12, p. 17, pl. 4, fig. 15, 1939.

When *A. laticaudum* was described the nontypical form of one cranidium was noted. However, study of the series of species from Two Mile Canyon was required to define clearly both *A. laticaudum* and the new species. It is not yet certain that the other specimen assigned to *A. laticaudum* from the Wasatch Mountains near Brigham can remain in the species.

The holotype cranidium of *A. brighamense* is very close to *A. euchare* Resser from Two Mile Canyon. It differs from *A. laticaudum* in its narrower brim.

A. brighamense is characterized by a slender tapering glabella occupying about half the cranidial length. The usual furrows are present. Brim wide, concave, with a nearly semicircular anterior outline. The fixigenes are wider than the glabella. The eyes are small, situated behind the midpoint of the glabella, so that the eye lines slope back rather sharply.

Middle Cambrian, Spence; (loc. 55e) 4½ miles north of Brigham, Wasatch Mountains, Utah.

Holotype.—U.S.N.M. No. 102325.

AMPHOTON Lorenz, 1906

Amphoton blackwelderi, new species

Dolichometopus deois WALCOTT (part), Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 216, pl. 22, fig. 1h, 1913.

This species is larger than the average for the genus. Unfortunately, the cranidium was not illustrated, although several examples are present in the material with the holotype pygidium. Compared with *A. asiaticum* and *A. deois,* this cranidium is characterized by its smoothness and the presence of a rather short but prominent occipital spine. The holotype pygidium is smoother than that of the other species, and the axis is relatively somewhat shorter. While the pleural ribs are not much more prominent than in the other species, they appear to be sharper and narrower owing to the abrupt slope into the furrows, but when viewed from the side or the rear they seem to be much less prominent. The axis does not stand very high above the pleural platforms and slopes off more gently in the rear.

Middle Cambrian, Changhia; (loc. C4) 3 miles southwest of Yenchuang, Sintai district, Shantung, China.

Holotype.—U.S.N.M. No. 58248; paratypes, No. 60832.

Amphoton alceste (Walcott)

Dolichometopus alceste WALCOTT, Proc. U. S. Nat. Mus., vol. 29, p. 94, 1905; Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 215, pl. 22, figs. 3-3b, 1913.

Middle Cambrian, Changhia; (locs. C4, C1) southwest of Yenchuang, Sintai district, Shantung, China.

Holotype.—U.S.N.M. No. 58249; paratypes, Nos. 58250, 58251.

Amphoton kaipingense, new species

Dolichometopus deois SUN, Geol. Surv. China, Pal. Sinica, ser. B, vol. 1, fasc. 4, p. 81, pl. 5, fig. 9, 1924.

This smooth cranidium cannot belong with the furrowed *A. deois* or *A. asiaticum.* Its glabella is relatively shorter (disregarding Walcott's incorrect drawings).

Middle Cambrian, Nanchuang; Kwang-hsi-ying, Luanchou, Kaiping basin, Chihli, China.

Holotype.—Geol. Surv. China No. 623.

Amphoton hyrie (Walcott)

Dolichometopus hyrie WALCOTT, Proc. U. S. Nat. Mus., vol. 30, p. 594, 1906; Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 218, pl. 22, figs. 6-6b, 1913.

Middle Cambrian, Changhia; (loc. C69) 4 miles east of Fang-lan-chön, Shansi, China.

Holotype.—U.S.N.M. No. 58257; paratypes, Nos. 58258, 58259.

ANOMOCARELLA Walcott, 1905

Anomocarella shantungensis, new species

Anomocarella chinensis Walcott (part), Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 200, pl. 20, fig. 3b, 1913.

This species is like *A. chinensis* in every respect except the structure of the brim. In *A. shantungensis* the preglabellar area has about the same proportions, convexity, and slope as in *A. chinensis,* but the rim is considerably wider.

Middle Cambrian, Changhia; (loc. C57) 4 miles north of Sintai; and (loc. C4) 3 miles southwest of Yenchou, Shantung, China.

Holotype.—U.S.N.M. No. 58207.

AOJIA Resser and Endo, 1935

Aojia biston (Walcott)

Anomocare biston Walcott, Proc. U. S. Nat. Mus., vol. 29, p. 49, 1905.

Anomocarella biston Walcott, Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 198, pl. 21, fig. 2, 1913.

Middle Cambrian, Changhia; (loc. C2) 2 miles south of Yenchuang, Shantung, China.

Holotype.—U.S.N.M. No. 58201.

Aojia undata (Walcott)

Ptychoparia undata Walcott, Proc. U. S. Nat. Mus., vol. 30, p. 589, 1906.

Anomocarella undata Walcott, Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 210, pl. 21, fig. 5, 1913.

Middle Cambrian, Changhia; (loc. C71) 4 miles southwest of Tungyü, Shansi, China.

Holotype.—U.S.N.M. No. 58202.

ASIOPTYCHASPIS Kobayashi, 1933

Asioptychaspis shansiensis (Sun)

Ptychaspis shansiensis Sun, Geol. Surv. China, Pal. Sinica, ser. B, vol. 7, fasc. 2, p. 29, pl. 4, figs. 1-6, text fig. 3, 1935.

Upper Cambrian, Licheng; Shangyaocheng, Licheng, Shansi, China.

Cotypes.—Nat. Peiping Univ. Nos. S1202-S1208.

Asioptychaspis brevica (Sun)

Ptychaspis brevicus Sun, Geol. Surv. China, Pal. Sinica, ser. B, vol. 7, fasc. 2, p. 28, pl. 4, figs. 7-9, 1935.

Upper Cambrian, Wolungshan; Huolu, Hopei, China.

Cotypes.—Nat. Peiping Univ. Nos. S1209-S1211.

Asioptychaspis asiatica (Resser and Endo)

"Ptychaspis" asiatica RESSER and ENDO, Manchurian Sci. Mus. Bull. 1, pt. 2, p. 272, pl. 56, figs. 4-9, 1937.

Upper Cambrian, Yenchou (*Asioptychaspis* zone); Shang-ping-chou, 8 miles east of Liao-yang and at Yen-chou-chang, 4.5 miles south of Yentai, Taitzuho district, Manchoukuo.

Cotypes.—U.S.N.M. Nos. 86895, 86896.

Asioptychaspis chihliensis Resser

Ptychaspis subglobosa SUN (part), Geol. Surv. China, Pal. Sinica, ser. B, vol. 7, fasc. 2, p. 28, pl. 4, figs. 10, 11, 1935.

Upper Cambrian, Taoyuan; Ting-chia-tsun, western hills of Peiping, Chihli, China.

Cotypes.—Nat. Peiping Univ. Nos. S1212, S1213.

Asioptychaspis suni (Grabau)

Ptychaspis suni GRABAU, *in* Sun, Geol. Soc. China, Bull. 2, Nos. 1-2, p. 98, 1923; *in* Sun, Geol. Surv. China, Pal. Sinica, ser. B, vol. 1, fasc. 4, p. 75, pl. 5, figs. 4a, 4b, 1924.

Upper Cambrian, Fengshan; Yehli, Hopei, China.

Holotype and paratype.—Geol. Surv. China No. 609.

Asioptychaspis sphaerica (Resser and Endo)

Ptychaspis sphaerica RESSER and ENDO, *in* Endo, Iwanami Lecture Ser., Geol. Pal., p. 89, text figs. 10-13, December 1931; Manchurian Sci. Mus. Bull. 1, pt. 2, p. 273, pl. 55, figs. 10-13, 1937.

Upper Cambrian, Yenchou; slope of Paishan near Chinchia-chengtzu, Manchoukuo.

Cotypes.—U.S.N.M. No. 86897.

BERKEIA Resser, 1937

Berkeia affinis (Walcott)

Ptychoparia (*Euloma?*) *affinis* WALCOTT, U. S. Geol. Surv. Monogr. 8, p. 54, pl. 10, fig. 12, 1884; idem, 32, p. 457, pl. 65, fig. 8, 1899.

Iddingsia affinis RESSER, Smithsonian Misc. Coll., vol. 95, No. 22, p. 14, 1937.

Recently a large number of Upper Cambrian specimens and species have been photographed and described preparatory to publication. One of the groups thus investigated is *Iddingsia-Berkeia-Dokimocephalus-Burnetia.* Now that a number of species are known in each, it is possible to set more natural limits to the genera.

Upper Cambrian, Dunderberg; (loc. 63) northeast of Adams Hill, Eureka district, Nevada.

Holotype.—U.S.N.M. No. 24642.

BLOUNTIA Walcott, 1916

Blountia arguta, new species

Maryvillia arion WALCOTT (part), Smithsonian Misc. Coll., vol. 64, No. 5, p. 400, pl. 64, figs. 4a, c, 1916; RESSER, Geol. Soc. Amer. Spec. Pap. 15, p. 87, pl. 13, fig. 9, 1938.

The pygidia removed from *Maryvillia arion* are the basis for this species. About 10 specimens are in hand, but the cranidium has not been located among the lot containing the pygidia. All of the specimens are exfoliated so that axial and pleural furrows are visible. There is so little depression or change of slope at the inner edge of the border that it is doubtful whether the test showed any trace of furrows. This pygidium is not highly arched in either direction, although it is rather evenly convex in all parts, except in the front center.

Upper Cambrian, Nolichucky; (loc. 123b) ½ mile east of Rogersville, Tennessee.

Holotype.—U.S.N.M. No. 62827; paratypes, Nos. 62828, 94968.

Blountia terranovica, new species

Maryvillia arion LOCHMAN, Journ. Pal., vol. 12, No. 5, p. 469, pl. 57, fig. 4, 1938.

The illustration of this pygidium shows that the Newfoundland species has a shorter, wider tail than *B. arion*, with a shorter, less-tapered axis. Judging from the illustrations *B. terranovica* has a rather strong dorsal furrow, and if the specimen is not exfoliated, the anterior pleural and marginal furrows are also clearly defined.

Upper Cambrian, Petit Jardin; south shore of Cape St. George, Newfoundland.

Holotype.—Yale Peabody Mus. No. 15821.

Blountia widnerensis, new species

Maryvillia masadensis RESSER (part), Geol. Soc. Amer. Spec. Pap. 15, pl. 12, fig. 40, 1938.

Only the figured pygidium is in hand from loc. 22n, but from the other locality an excellent cranidium accompanies several pygidia.

The glabella is large, smooth, tapered to a rounded front, and stands above the dorsal furrow. Occipital furrow so faint as to be visible only in strong cross light. Opposite the eye the fixigenes are less than a fifth the glabellar width. Forward of the eye the facial suture diverges somewhat and rounds the anterior angle, remaining intramarginal possibly nearly to the center. Eyes rather small and situated well forward. Behind the eyes the facial suture diverges rapidly, forming posterolateral limbs that exceed the width of the glabella at the neck ring. These limbs turn rather sharply backward in their outer portion. Since their width decreases gradually, this backward direction is attained by the flexure of the rear margin. The brim width equals about one-fourth of the glabellar length. As a whole it is concave, owing to the depression of the preglabellar area and the more nearly horizontal position of the rim. Viewed in light coming directly from the front, the preglabellar area appears to be about one-third the width of the rim, but when the light comes from the sides, the rim seems to be so wide in the middle that the preglabellar area is destroyed. This illusion is due to the depression of the medial portion of the preglabellar area. Taken as a whole, the cranidium has its maximum convexity in the rear portion, but since the anterior part, although curved little in itself, slopes downward sharply, the convexity of the whole is thereby greatly accentuated. In cross section the cranidium is evenly convex.

Little need be said about the pygidium, since it is normal in all respects. It is moderately convex and in the rear comes to a fairly sharp angle.

Upper Cambrian, Nolichucky; (loc. 22n) Widner Branch, 1½ miles southwest of Masada, and (loc. 35s) 4 miles northeast of Abingdon, Virginia.

Holotype.—U.S.N.M. No. 102311; paratypes, No. 102312.

Blountia antecepta, new species

Maryvillia georgica Resser (part), Geol. Soc. Amer. Spec. Pap. 15, p. 88, pl. 12, fig. 42, 1938.

In this instance only the pygidia were located. They are typical in all respects, but owing to compression of the rock are nearly flat. Considerable calcite veining also distorts them slightly.

Upper Cambrian, Nolichucky; (loc. 96x) 1 mile north of Adairsville, Georgia.

Holotype.—U.S.N.M. No. 102313.

Blountia angustata, new species

Maryvillia ariston Walcott (part), Smithsonian Misc. Coll., vol. 64, No. 5, p. 401, pl. 64, fig. 5a, 1916; Resser (part), Geol. Soc. Amer. Spec. Pap. 15, p. 87, pl. 13, figs. 4, 6, 1938.

This species is close to *B. arguta.* Walcott recognized a difference which seems to hold for all specimens. The main difference distinguishing *B. angustata* is the narrowing of the tail. Also the rear margin becomes more angular, and at the same time has greater convexity near the edge.

Upper Cambrian, Nolichucky; (locs. 119, 120) Copper Ridge, about 11 miles northwest of Knoxville, and (loc. 126a) Gap Creek, 10 miles east of Knoxville, Tennessee.

Holotype.—U.S.N.M. No. 94997; paratype, No. 62830.

BRISCOIA Walcott, 1924

Briscoia winchelli, new species

Dicellocephalus minnesotensis WINCHELL (part), Amer. Journ. Sci., vol. 37, p. 229, 1864.

Dicellocephalus pepinensis WINCHELL (part), idem.

Dikelocephalus ? limbatus WALCOTT (part), Smithsonian Misc. Coll., vol. 57, No. 13, p. 369, pl. 65, fig. 8, 1914.

This species is represented rather abundantly in the collections at present available. Cranidia are seldom complete. Winchell's material contains the anterior half of a cranidium, and the Whitfield collection at the University of California has a nearly complete example. Pygidia and libragenes are rather well represented.

This species is characterized by normal development in all its parts. The glabella is large, although it maintains normal proportions. It stands above the dorsal furrow and is marked by three sets of furrows. (It must be remembered that only exfoliated specimens are available in sandstone matrix.) The brim is simple, slightly concave and about half the glabellar length. The fixigenes are confined practically to the palpebral lobes since the facial suture cuts close to the dorsal furrow at the anterior end of the eye. From that point forward the suture diverges rather rapidly forming large anterior angles. Behind the eye the suture forms the long, narrow posterolateral limbs characteristic of the genus. The eyes are strongly bowed and are situated well toward the rear. The libragene is wide and has a wide, slightly concave border that extends into short genal spines. A wide doublure underlies the border and leaves only small triangular ocular platforms.

The pygidium on which the species is based is characterized by a slender axis, which occupies a little more than half the pygidial length. At least four rings are visible. The axis terminates in a postaxial ridge. The pleural lobes extend into a wide flaring, slightly concave border. Both the pleural furrows and grooves extend out nearly to the edge of the tail. They subdivide the pleura nearly equally.

Upper Cambrian, Franconia; (loc. 81b) near Devils Lake, Sauk County, Wisconsin.

Holotype.—U.S.N.M. No. 58625; paratypes, Univ. Michigan Nos. 4876, 4873.

CAMARASPIS Ulrich and Resser, 1924

Camaraspis cushingi (Ruedemann)

Agraulos cushingi RUEDEMANN (part), New York State Mus. Bull., No. 189, p. 89, pl. 30, figs. 1, 2, 4, 1916.

Upper Cambrian, Potsdam (Theresa member); Greenfield, northwest of Saratoga, New York.

Lectotype and paratype.—N.Y.S.M. No. 3658; casts, U.S.N.M. No. 102314.

Camaraspis ruedemanni, new species

Agraulos cushingi RUEDEMANN (part), New York State Mus. Bull. No. 189, p. 89, pl. 30, fig. 3, 1916.

In New York, as generally happens elsewhere, several species of *Camaraspis* are found together. Most of Ruedemann's specimens belong to *C. cushingi,* which is rather convex in both directions, but one of the figured cranidia is much flatter longitudinally and has the glabella less clearly defined (drawing misleading). Furthermore, the glabella also is shorter. *C. ruedemanni* has rather sharply depressed posterolateral limbs which arches the cranidium in the rear.

Occurrence same as preceding.

Holotype.—N.Y.S.M.; cast, U.S.N.M. No. 102315.

CHARIOCEPHALUS Hall, 1863

Chariocephalus gibbsi (Whitfield)

Conocephalites gibbsi WHITFIELD (part), Ann. Rep. Wisconsin Geol. Surv., vol. 2, p. 67, 1873-1877.

Crepicephalus gibbsi WHITFIELD (part), Ann. Rep. Wisconsin Geol. Surv. for 1879, p. 50, 1880; (part), Geol. Wisconsin, vol. 4, p. 184, pl. 10, fig. 13, 1882.

Ptychoparia gibbsi WALCOTT (part), Smithsonian Misc. Coll., vol. 64, No. 3, p. 204, 1916.

Upper Cambrian, Franconia; (loc. 86W.), Berlin, Wisconsin.

Holotype.—Wisconsin Acad. Sci.; cast, U.S.N.M. No. 108496.

CHUANGIA Walcott, 1911

Chuangia endoi, new name

Chuangia nitida ENDO, Manchurian Sci. Mus. Bull. 1, pt. 3, p. 325, pl. 67, fig. 1, 1937.

This is not conspecific with *Chuangia nitida* Walcott, which is equivalent to *C. buchrucheri.*

Upper Cambrian, Paishan; Tang-shih-ling hill, southeast of Yentai colliery, Manchoukuo.

Holotype.—Manchurian Sci. Mus. No. 1322.

Chuangia monkei (Lorenz)

Schantungia monkei LORENZ, Deutsch. Geol. Ges. Zeitschr., vol. 58, No. 2, p. 81, pl. 5, figs. 17, 18, 1906.

Schantungia crassa LORENZ, idem, p. 95, 1906.

Pagodia monkei WALCOTT, Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 7, 1913.

Upper Cambrian, Changshan; Tsing-chou, Shantung, China.

Cotypes.—Freiburg Mus.

Chuangia hopeiensis, new species

Chuangia batia SUN, Geol. Surv. China, Pal. Sinica, ser. B, vol. 7, fasc. 2, p. 21, pl. 1, figs. 14-17, 1935.

Compared with *C. batia,* this species has a wide brim. Sun's specimens are evidently exfoliated and consequently have deeper furrows than appear on the outer surface. The eyes are of normal size, situated just behind the midpoint of the glabella.

Upper Cambrian, Wolungshan; Huolu, Hopei, China.

Cotypes.—Nat. Peiping Univ. Nos. S1124-S1127.

Chuangia huoluensis, new species

Chuangia nitida SUN, Geol. Surv. China, Pal. Sinica, ser. B, vol. 7, fasc. 2, p. 25, pl. 1, figs. 8, 9, 1935.

The cranidium is short, with prominent palpebral lobes, and has a straight front margin. The pygidium is more transverse than either *C. batia* or *C. hopeiensis.* It also has a less circular outline, hence the pleural lobes narrow toward the anterior angles.

Upper Cambrian, Wolungshan; Huolu, Hopei, China.

Cotypes.—Nat. Peiping Univ. Nos. S1118, S1119.

CLAVASPIDELLA Poulsen, 1927

Clavaspidella tolli, new species

Bathyuriscus howelli VON TOLL, Mem. Acad. Imp. Sci. St. Petersburg, ser. 8, vol. 8, No. 10, p. 30, pl. 2, fig. 11, 1899.

Toll recognized the true affinity of this pygidium but failed to see that it was different from *C. howelli.* Compared with that species, *C. tolli* has a wider pygidium, a slightly shorter and more slender axis. This species is characterized by its slender tapering axis and rather shallow pleural furrows.

Middle Cambrian, below Arürach, right bank Olenek River, Siberia.

Holotype.—Acad. Sci. Leningrad.

Clavaspidella piochensis, new species

Olenoides spinosus WALCOTT (part), U. S. Geol. Surv. Bull. 30, p. 184, pl. 25, fig. 6a, 1886.

The cranidium from Pioche, Nev., illustrated by Walcott, is not in the matrix of the pink Chisholm shale but occurs in a yellowish micaceous sandy shale. According to present knowledge such rock occurs only in the Comet shale, and we may tentatively assume that this specimen was derived from that formation.

The original illustrations show that this cranidium is not the same as *Zacanthoides spinosus* from the Eureka district, and a little further comparison shows that it is a species of *Clavaspidella* and not of *Zacanthoides.* Naturally after this discovery one turns to *C. howelli,* also from near Pioche, to test specific identity. While Walcott's figures of *C. howelli* appear quite different from *C. piochensis,* the real distinction has been accentuated by poor drawing. Nevertheless, *C. piochensis* is specifically distinct from *C. howelli.*

C. piochensis is characterized by a large glabella which expands considerably in the anterior half. Four pairs of glabellar furrows are clearly shown. The brim consists of a simple upturned rim. Fixigenes confined to the palpebral lobes and small triangular areas at the anterior angles. Anterior facial suture diverges considerably. A remarkable feature is the extraordinary length of the posterolateral limbs. Surface features are not preserved, except that the occipital ring seems to be wrinkled.

Middle Cambrian, Comet?; Pioche, Nevada.

Holotype.—U.S.N.M. No. 102316.

CONASPIS Hall, 1863

Conaspis whitehallensis (Walcott)

Conocephalina whitehallensis WALCOTT, Smithsonian Misc. Coll., vol. 57, No. 9, p. 269, pl. 44, figs. 9-11a, 1912.

This species was evidently referred to *Conokephalina* on the basis of the illustration. The type cranidium was not completely freed from the matrix, and in some manner the lighting in the photograph accentuated the convexity of the fixigenes and preglabellar area so that it resembled the cranidium on which *Conokephalina* is founded. Careful comparison with the type of *Conaspis, C. perseus,* shows that this species is more properly referred to that genus, although doubt still remains concerning the trilobite to which *C. perseus* properly applies.

Upper Cambrian, Theresa; (loc. 110a) Whitehall, Washington County, New York.

Holotype.—U.S.N.M. No. 58579; paratypes, Nos. 58580, 58581.

COOSIA Walcott, 1911

Coosia alethes (Walcott)

Blountia alethes WALCOTT (part), Smithsonian Misc. Coll., vol. 64, No. 5, p. 397, pl. 64, figs. 1, 1a, 1916 (not figs. 1b, 1c = *Maryvillia arion*).
Coosia alethes RESSER (part), Geol. Soc. Amer. Spec. Pap. 15, p. 71, 1938.

It is necessary to restrict this species to the cranidium. Pygidia are present in the collection but were not illustrated. Those formerly assigned to the species belong to *Maryvillia*, as that genus is now construed.

Upper Cambrian, Nolichucky; (loc. 123b) ½ mile east of Rogersville, Tennessee.

Holotype.—U.S.N.M. No. 62821.

CREPICEPHALINA Resser and Endo, 1935

Crepicephalina RESSER and ENDO, *in* Kobayashi, Journ. Fac. Sci. Imp. Univ. Tokyo, sect. 2, vol. 4, pt. 2, p. 277, 1935; Manchurian Sci. Mus. Bull. 1, pt. 2, p. 195, 1937.
Mesocrepicephalus KOBAYASHI, Journ. Fac. Sci. Imp. Univ. Tokyo, sect. 2, vol. 4, pt. 2, p. 277, 1935.

When Kobayashi established *Mesocrepicephalus* and at the same time recognized the validity of *Crepicephalina* Resser and Endo, he based his study entirely on Walcott's figures of *C. convexa* and *C. damia,* without observing that both are incorrectly drawn. A study of the types shows that both are generically identical, even though the cranidium of *C. damia* appears somewhat different, owing to the very great concavity of the brim and the steepness of the slope from the glabella into it. A difference is also found in the pygidium, for the spines are heavier in some species than in others, but in the supposedly related *Tricrepicephalus,* variation in this respect goes to great extremes, hence this fact need not be given generic importance in this case.

Genotype.—*Crepicephalus convexus* Walcott.

Crepicephalina damia (Walcott)

Crepicephalus damia WALCOTT, Proc. U. S. Nat. Mus. vol. 29, p. 92, 1905; (part), Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 141, pl. 13, figs. 14, 14b, 1913.
Menocephalus acerius WALCOTT (part), idem, p. 174, pl. 16, fig. 10a, 1913.
Mesocrepicephalus damia KOBAYASHI, Journ. Fac. Sci. Imp. Univ. Tokyo, sect. 2, vol. 4, pt. 2, p. 277, 1935.

Middle Cambrian, Changhia; (loc. C18) 1 mile east of Changhia, Shantung, China.

Holotype.—U.S.N.M. No. 57986; paratypes, Nos. 57988, 58090.

Crepicephalina kaipingensis (Sun)

Conokephalina kaipingensis SUN, Geol. Surv. China, Pal. Sinica, ser. B, vol. 1, fasc. 4, p. 47, pl. 3, figs. 4 a-b, 1924.

Crepicephalus sp. SUN, idem, p. 49, pl. 3, fig. 6, 1924.

Lower Cambrian, Manto; Chengshan, Chaokouchuang, Kaiping basin, Chihli, China.

Cotypes.—Geol. Surv. China Nos. 550, 551, 555.

DICTYELLA Kobayashi, 1933

Dictyella manchurica (Kobayashi)

Hysterolenus (?) *manchuricus* KOBAYASHI, Jap. Journ. Geol. and Geogr., vol. 11, Nos. 1, 2, p. 150, pl. 15, fig. 6, 1933; ENDO, Manchurian Sci. Mus. Bull. 1, pt. 3, p. 342, pl. 71, fig. 4, 1937.

Upper Cambrian, Yenchou; Paichiashan, near Chinchiachengtzu, Manchoukuo.

Holotype.—Geol. Inst. Univ. Tokyo (cast, U.S.N.M. No. 94062); plesiotypes, Manchoukuo Sci. Mus. No. 1319.

DORYPYGE Dames, 1883

Dorypyge DAMES, von Richthofen's China, vol. 4, p. 23, Berlin, 1883.

Like most other Cambrian genera of long standing, *Dorypyge* needs revision. Species of *Kootenia* and *Olenoides* from North America and Siberia were referred to it and subsequently removed. Atlantic Province species are also assigned to *Dorypyge,* and the problem created by those references is discussed on a subsequent page. Here are listed the valid Asiatic species now in *Dorypyge.* Cross references to forms based on described material are included.

D. bigranosa Resser and Endo
D. bispinosa Walcott
D. damesi Resser and Endo
D. kidoi Resser and Endo
D. leei Resser and Endo
D. manchuriensis Resser and Endo
D. matsushitai Resser and Endo
D. perconvexa Resser and Endo
D. pergranosa Resser and Endo
D. richthofeni Dames
D. richthofeni Walcott = { *D. suni*, *D. manchuriensis*, *D. damesi* }
D. richthofeni Lorenz = *D. lorenzi*
D. richthofeni laevis Walcott = *D. laevis*
D. semicircularis Resser and Endo
D. taitzuensis Resser and Endo
D. toyami Resser and Endo

Dorypyge richthofeni Dames

Dorypyge richthofeni DAMES, *in* von Richthofen's China, vol. 4, p. 24, pl. 1, figs. 1-6, Berlin, 1883; KOBAYASHI, Journ. Geol. Soc. Japan, vol. 44, No. 524, p. 434, pl. 17, figs. 13a, 13b, 1937.

The following is a free translation of the essential portions of Dames' excellent description. It is reprinted because the original is hard to get.

The glabella is highly arched, bounded by practically parallel longitudinal furrows, which deepen into pits near the frontal rim; anteriorly bluntly rounded off. The glabella reaches to the anterior edge; in front of it there is only a narrow obliquely upturned frontal rim. Three pairs of horizontal glabellar furrows are sharply impressed on the moulds, and also appear on the shell surface. On the former all pairs make very shallow furrows, but on the shell surface one can scarcely see the furrows, except that they have been made clearer because in them the granulations which cover the rest of the surface are wanting, and hence they appear as narrow smooth strips. The fixed cheeks are arched evenly, although clearly less than the glabella; the eye lobes are situated at about the middle and extend from about the last to the first pair of glabellar furrows. The facial sutures run forward from them to the anterior margin, converging a little, and behind the eyes they diverge very rapidly to the posterior margin. The neck ring is small and sharply defined on the fixed cheeks, and behind the glabella is swollen, and from it a raised spine is directed obliquely backward. This spine is hollow and appears to have had considerable length.

The surface of the cranidium is covered with small papillae which are distributed in such a manner that they are smaller, more numerous and more crowded in the anterior than in the posterior portions, and further, that they are larger and farther apart on the cheeks than on the glabella. The dorsal, glabellar and occipital furrows lack the papillae.

The pygidium of the largest individual is about 15 mm. long and 24 mm. wide at the front and is of a rounded triangular shape. The rhachis of this specimen is about 8 mm. wide at the top, highly arched, sharply defined both on the sides and behind. At the rear it drops off almost perpendicularly and does not quite reach the posterior margin, leaving a space something like 2 mm. wide. It is divided by deep furrows into four segments. In well-preserved specimens, close to its rounded-off end, one can observe one or two more rather shallow furrows as indications of a very poor further segmentation. The surface is covered with papillae, which, however, occur in the furrows between the segments only along the median line, and on the whole, become somewhat fewer and smaller toward the rear. The lateral portions are much less arched than the rhachis, and drop off to an almost horizontal border. They are divided into four segments by deep and wide furrows, which stop at the sharply defined horizontal border. The relative position of the axial and pleural furrows is rather strange. They alternate, that is the pleural furrows meet the axial rings and oppositely, the axial furrows meet the pleural segments. The segments have a shallow furrow on their surface which is delimited by two ridges. It is only on these ridges that individual papillae occur, the segment being otherwise smooth. The border of the pygidium is drawn out into rounded, pointed spines. Each of the four segments gives rise to a short spine, which is directed almost straight out in the first segment, while in the following ones, the spines are gradually turned farther back. These four spines on each side are about of equal length. Next behind the last of these four pairs of spines, a fifth arises, which is distinguished from the others by its considerable thickness and length, and it is directed straight backward. At the posterior margin, between this fifth pair of spines, is a further pair of pointed protuberances, just about at the point where the longitudinal furrows delimiting the rhachis would reach the posterior edge, if they were projected.

Two corrections should be made in the foregoing description. First, the statement that the facial suture converges anterior to the eye is not true. Examination of Dames' types in Berlin revealed that none of the specimens were prepared completely, simply being drawn as far as they came free of the matrix when the containing rock was broken. Since the edges are turned sharply down, it is difficult to uncover completely the anterior angles, and consequently, most illustrations are incorrectly drawn at these points. If, however, the down-turned anterior angles are entirely cleaned out, the anterior facial suture is seen to diverge at the average angle for the genus.

The second slight correction to be made in Dames' description is regarding distribution of granules on the pygidial rhachis (provided, of course, that Dames was discussing the same tail as is herewith associated with the cranidium). There are two sets of granules, the larger occurring only on the upper surfaces of the axial rings, thinning out almost to extinction on the pleura, while a set of smaller granules occupies the slopes into the axial furrows, the bottoms of which are smooth. It might be mentioned further that the large fifth marginal spine is not only directed backward, but turns up from the horizontal plane considerably more than in most other species.

When Endo and I restudied the question of the *Dorypyge* species, we still had the incorrect notion that Dames' types were from Shantung. Since Dames got his specimens in Manchoukuo, it is necessary to restrict *D. richthofeni* to them, which eliminates the species from China proper. The specimens used by Lorenz, by Walcott, and by Sun all belong to unnamed species as indicated in the following pages.

Middle Cambrian, Taitzu; Wulopu, south of Hsiaoshih, Manchoukuo.

Lectotype and paratypes.—Natur. Mus. Berlin.

Dorypyge laevis Walcott

Dorypyge richthofeni laevis Walcott, Proc. U. S. Nat. Mus., vol. 30, p. 573, 1906; Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 109, pl. 8, figs. 2, 2b, 1913.

No change in the nomenclature of this species is necessary except to recognize it as a full species, but a brief discussion is desirable.

As stated in the original description the surface lacks pustules and therefore stands alone among described Chinese forms. However, examination in proper light reveals irregularity beneath, rather than on, the surface. Besides its smoothness this species is not so highly arched in either direction as *D. richthofeni,* neither are the anterior angles of the fixigenes turned down so sharply. The eyes appear to be a little farther forward; glabellar furrows are represented by the faintest of markings and the occipital furrow, both on the fixigenes and glabella, is very much less impressed. *D. laevis* has a longer and stouter, erect neck spine. An associated smooth libragene is regarded as representing the species.

Fragments of a smooth pygidium are found at another locality with the illustrated hypostoma and a head which appears to agree with the holotype. Besides being smooth, the pygidium is characterized by its general flatness, although the axis remains well above the pleural lobes, and is well defined by the dorsal furrow. Both the axial and pleural furrows are shallower than usual. Slight traces of pleural grooves are visible.

Middle Cambrian, Changhia; (loc. C72) east of Fang-lan-chön, and (loc. C71) southwest of Tungyü, Shansi, China.

Holotype, paratypes, and plesiotypes.—U.S.N.M. Nos. 57883-57885.

Dorypyge lorenzi, new species

Olenoides (Dorypyge) richthofeni LORENZ, Deutsch. Geol. Ges. Zeitschr., vol. 58, No. 2, p. 67, pl. 4, figs. 1-5, 1906.

The specimens Lorenz assigned to *D. richthofeni* represent a distinct species. A cast of the pygidium illustrated as figure 3 is in the United States National Museum collections. Whether or not figure 4 is the same species cannot be told from Lorenz' figures, except that it seems to represent a more granulose form.

As illustrated by Lorenz the cranidium is normal in size and proportions. The glabella is somewhat protuberant and has faint furrows. The granules are evidently scattered, and the neck ring no doubt had a sizable spine. Fixigenes are shown to be of normal size and shape. The cast of the pygidium in the United States National Museum shows four slender marginal spines and a fifth long and heavy spine. The rear pair are obscured by matrix. Granulation is restricted to a few rows on the ridges of the axis and pleura.

Middle Cambrian, Changhia; Laiwu, Shantung, China.

Holotype and paratypes.—Geol. Inst. Freiburg im Br.

Dorypyge suni, new species

Dorypyge richthofeni WALCOTT (part), Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 108, pl. 8, figs. 1, 1e, 1913 (not 1a-d, f = *D. shantungensis*).

Of the forms formerly assigned to *D. richthofeni* by Walcott several are easily distinguished. To one of these the name *D. suni* is given in recognition of the work by Dr. Y. C. Sun on the Cambrian of China.

D. suni has faint glabellar furrows. The granules on the glabella are about the same as on the corresponding parts of *D. richthofeni*, but are underlain by an irregular and poorly developed system of fine anastomosing lines, and differ further in that they maintain approximately the same size and density on both the glabella and fixigenes. Furthermore, in cross section the convexity of the glabella, but not of the fixigenes, is greater.

The pygidium assigned to the species has only a few granules on the axis. The pleural lobes are marked by rather strong wirelike lines on the edges where the slope into the furrow begins.

Middle Cambrian, Changhia; (loc. C1) 2 miles south of Yenchuang, and (loc. C57) 3 miles south of Kaokiapu, Shantung, China.

Holotype and paratypes.—U.S.N.M. Nos. 57876, 57877.

Dorypyge shantungensis, new species

Dorypyge richthofeni WALCOTT (part), Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 108, pl. 8, figs. 1a, 1c, 1d, 1f, 1913 (not 1, 1b, 1e = *D. suni*).

The remaining specimens referred by Walcott to Dames' species, after removal of *D. suni,* constitute another well-defined species. Size and shape are similar to *D. suni,* but the surface is more strongly granulated by rather evenly distributed granules of nearly even size. The macrospinal development involves the fourth pygidial spine, back of which is only a pair of nodes. Figure 1b of Walcott is doubtful.

Middle Cambrian, Changhia; (locs. C19, 29) Changhia south of Tsi-nan-fu, and (loc. C1) Yenchuang, Sintai district, Shantung, China.

Holotype.—U.S.N.M. No. 57878; paratypes, Nos. 57877, 57879, 57881.

Dorypyge chihliensis, new species

Dorypyge richthofeni SUN, Geol. Surv. China, Pal. Sinica, ser. B, vol. 1, fasc. 4, p. 29, pl. 2, figs. 3a-d, 1924.

Among the specimens Sun referred to *D. richthofeni,* one species is clearly indicated by Sun's illustration, and it is possible that figure 3a represents another.

Compared with *D. richthofeni* the Chihli species has a wider glabella, fewer granules, and possibly wider fixigenes. The glabella is less protuberant and the rim wider. In the pygidium the ribs, spines, and axis are all more robust, and the spines are curved backward to a greater degree. Sun's specimens are only partly exfoliated, hence it is clear that *D. chihliensis* has deep and wide pygidial furrows. The first four pairs of spines increase in size and length rearward, and the fifth is rather stout and must have been as long as the pygidium.

Middle Cambrian, Changhia; Chengshan, Chaokouchuang, Chihli, China.

Holotype.—Geol. Surv. China No. 519; paratypes, Nos. 517, 520.

Further revision of the Asiatic species is necessary, but the foregoing will suffice for present purposes. We need only add that the Geological Survey of China has on hand a number of undescribed forms, so that the genus is represented by many species.

Dorypyge slatkowskii (Schmidt) from Siberia is a typical *Kootenia*. (See page 27.)

ATLANTIC PROVINCE SPECIES REFERRED TO DORYPYGE

Two species referred to *Dorypyge* are described from Denmark, four from England, and four from New Brunswick, all of which are in the Baltic division of the Atlantic Province. The list shows present reference.

Denmark
- *D. danica* Grönwall
- *D. oriens* Grönwall

England
- *D. lakei* Cobbold = *Kootenia lakei*
- *D. reticulata* Cobbold = *Kootenia reticulata*
- *D.* cf. *richthofeni* Nicholas = *Dorypyge* sp.
- *D. rushtonensis* Cobbold and Pocock

New Brunswick
- *D. horrida* Matthew = *Olenoides horridus*
- *D. quadriceps valida* Matthew = *Kootenia valida*
- *D. wasatchensis acadica* Matthew = *Olenoides acadicus*

D. cf. *richthofeni* Nicholas consists of fragments too imperfect for generic identification. Further, these fragments are not like the other species from England, seemingly being more like *Dorypyge* proper, and hence may stand as *Dorypyge* sp.

Matthews' species from New Brunswick, all based on pygidia, appear to fit into *Olenoides* and *Kootenia,* even though they constitute an element sharply at variance with the rest of the fauna. However, they are evidently related to the British forms also referred to *Kootenia.*

On the other hand the Bornholm species are nearer *Dorypyge* proper than they are to most of the British and New Brunswick species. It is interesting to note that two undescribed species occur together in the Manuels formation, southeastern Newfoundland. One is very close to, or perhaps identical with *D. danica* Grönwall. The other differs by having the first large marginal spine set much farther forward. Thus it is apparent the large spines shift position, and that different spines receive the macropleural development in different species just as happens in *Dorypyge*. The Bornholm and Newfoundland species are retained in *Dorypyge,* although they likely represent another genus. With them is placed *D. rushtonensis* Cobbold and Pocock from the Rushton area, Shropshire.

EMMRICHELLA Walcott, 1911

Emmrichella has full generic rank. Consequently the several species placed under *Ptychoparia* (*Emmrichella*) are to be regarded as belonging to *Emmrichella,* unless transferred to other genera because of incorrect identification.

Emmrichella nodosa (Sun)

Solenopleura nodosa SUN, Geol. Surv. China, Pal. Sinica, ser. B, vol. 1, fasc. 4, p. 56, pl. 4, figs. 3a, b, 1924.

Middle Cambrian, Nanchuang; Chaokouchuang, Luanhsien, Chihli, China.

Holotype and paratype.—Geol. Surv. China Nos. 577, 578.

EOAGNOSTUS Resser and Howell, 1938

Eoagnostus RESSER and HOWELL, Bull. Geol. Soc. Amer., vol. 49, No. 2, p. 216, 1938; KOBAYASHI, Journ. Fac. Sci. Imp. Univ. Tokyo, sect. 2, vol. 5, pt. 5, p. 122, 1939.

Archaeagnostus KOBAYASHI, idem.

Kobayashi copied the description of *Archaeagnostus* from a manuscript in my office but meanwhile we had decided to use a shorter name, and so published it.

Mallagnostus desideratus, also from the Schodack formation of the Hudson Valley, appears to represent a valid genus, thus constituting a second Lower Cambrian agnostid genus.

Eoagnostus primigeneus (Kobayashi)

Agnostus sp. WALCOTT, U. S. Geol. Surv. 10th Ann. Rep., p. 630, pl. 80, figs. 6, 6a, 1891.

Archaeagnostus primigeneus KOBAYASHI, Journ. Fac. Sci. Imp. Univ. Tokyo, sect. 2, vol. 5, pt. 5, p. 112, 1939.

Schodack: (loc. 43a) 1 mile northeast of Salem; and (loc. 38a) 2 miles south of North Granville, New York.

Cotypes.—U.S.N.M. No. 18328.

ETERASPIS Resser, 1935

It has been only in recent months that the existence of *Eteraspis* beyond Nevada was recognized. This genus has become a good guide fossil for the later Middle Cambrian formations. Besides the Eureka district it is now known from the Bloomington formation in the Wasatch Mountains, from the Maryville of the Appalachians, and possibly from the Eldon of the Canadian Rockies.

Eteraspis glabra (Walcott)

Asaphiscus (Blainia) glabra WALCOTT, Smithsonian Misc. Coll., vol. 64, No. 5, p. 394, pl. 63, figs. 1-1e, 1916.

Blountia glabra RESSER, ibid., vol. 95, No. 22, p. 3, 1937; Geol. Soc. Amer. Spec. Pap. 15, p. 64, pl. 12, figs. 31, 32, 1938.

Middle Cambrian, Maryville; (loc. 107x) Copper Ridge, 2 miles south of Heiskell, Tennessee.

Cotypes.—U.S.N.M. Nos. 62804-62808.

Eteraspis paula (Walcott)

Asaphiscus (Blainia) paula WALCOTT, Smithsonian Misc. Coll., vol. 64, No. 5, p. 395, pl. 62, figs. 2-2b, 1916.

Blania ? paula RESSER, Geol. Soc. Amer. Spec. Pap. 15, p. 62, pl. 9, fig. 3, 1938.

Middle Cambrian, Maryville: (loc. 90x) near Blaine, 3 miles south of Center, Alabama.

Lectotype.—U.S.N.M. No. 62802; paratype, No. 62803.

Eteraspis crassa (Resser)

Blountia crassa RESSER, Geol. Soc. Amer. Spec. Pap. 15, p. 64, pl. 12, fig. 23, 1938.

Middle Cambrian, Maryville; (loc. 107u) Copper Ridge, 2 miles south of Heiskell, Tennessee.

Holotype.—U.S.N.M. No. 94943.

EUPTYCHASPIS ULRICH, 1930

Euptychaspis minuta (Whitfield)

Ptychaspis minuta WHITFIELD, Ann. Rep. Wisconsin Geol. Surv. for 1877, p. 55, 1878; Geol. Wisconsin, vol. 4, p. 186, pl. 1, figs. 25, 26, 1882; CHAMBERLAIN, Geol. Wisconsin, vol. 1, p. 130, fig. 1883.

The specimens in the National Museum collections long ago identified as *Ptychaspis minuta* Whitfield agree with his illustrations and description, consequently they may be taken as typical of the species. In the original description the horizon is not clearly indicated. With these specimens and the description of the matrix in which Whitfield's types occur, it may be concluded that this species occurs in the Norwalk sandstone member. Several well-preserved examples show that this trilobite is typical of the genus *Euptychaspis*.

Upper Cambrian, Norwalk; Roberts Store, St. Croix County, and (loc. 78) Osceola, Wisconsin.

Holotype and paratype.—Univ. California.

EYMEKOPS Resser and Endo, 1937

Eymekops maia (Walcott)

Ptychoparia (?) maia Walcott, Proc. U. S. Nat. Mus., vol. 30, p. 592, 1906.
Conokephalina maia (Walcott), Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 139, pl. 13, fig. 13, 1913.

Middle Cambrian, Changhia; (loc. 70) 4 miles southwest of Tungyü, Shansi, China.

Holotype.—U.S.N.M. No. 57984.

Eymekops irma (Walcott)

Anomocarella irma Walcott, Proc. U. S. Nat. Mus., vol. 30, p. 584, 1906; Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 202, pl. 19, figs. 8, 8a, 1913.

Middle Cambrian, Changhia; (loc. C77) 4 miles southeast of Yauto, Wutai, Shansi, China.

Holotype.—U.S.N.M. No. 58173; paratype, No. 58174.

HANIWA Kobayashi, 1937

Haniwa suni (Kobayashi)

Ptychaspis suni Kobayashi, Jap. Journ. Geol. and Geogr., vol. 8, No. 3, p. 181, pl. 22, figs. 7, 8a, 1931.

Upper Cambrian, Chiushukou; Hua-lien-chai, Niuhsintai basin, Manchoukuo.

Cotypes.—Geol. Inst. Univ. Tokyo.

IDIOMESUS Raymond, 1924

Idiomesus disparilis (Hall)

Agnostus disparilis Hall, 16th Ann. Rep. New York State Cab. Nat. Hist., p. 179, pl. 10, figs. 25-27, 1863; Trans. Albany Inst., vol. 5, p. 171, pl. 5, figs. 25-27, 1867; Vogdes, Amer. Geol., vol. 9, p. 394, pl. 10, fig. 15, 1892.

It has long been known that this obscure trilobite is not an agnostid, but thus far no one ventured to place it into a more proper position, mainly because of the poor drawings published by Hall, and the fact that the matrix in which the specimens are preserved is rather coarse sand for the preservation of so small an object.

There may be some question raised respecting the validity of this reference to *Idiomesus*. Raymond's figure of the genotype does not show an occipital spine, and indicates that the glabella is delimited in front. The spine is so slender that it may have been overlooked, particularly since a node on the occipital ring is mentioned. It is my belief that the presence or absence of an occipital spine is only of specific value in most instances. In the second place, Raymond states that the glabella is not delimited in front in spite of the fact that his figure shows such a feature. So we may assume that *I. disparilis* may fall within reasonable limits of the genus *Idiomesus*. Until much more material is described it will do no harm to place this small trilobite in this genus. Several species and rather good material is available from Wisconsin. Outside of Wisconsin other species will add much to the understanding of the genus.

Upper Cambrian, Norwalk; (loc. 78) Osceola, Polk County, Wisconsin.

Cotypes.—Amer. Mus. Nat. Hist.

INOUYOPS, new genus

Characteristics of a species referred by Walcott to *Inouyia,* although somewhat like it in general appearance, warrant the erection of another genus. A second species is referred to the new genus even though it is not fully typical.

Inouyops is characterized by a long, slightly tapering glabella, on which three sets of furrows are faintly impressed. In cross section the glabella is not greatly convex, rising to a faint keel. A conspicuous feature is the greatly expanded neck ring which extends into an erect spine. The fixigenes average somewhat more than half the glabellar width, with the posterolateral limbs considerably depressed, which leaves the sharply curved eye lobes in a prominent position. The brim is wider than the fixigenes. It consists of a slightly upturned rim occupying about one-third the brim width, and a strongly convex vertically striated preglabellar area. The latter rises above the level of the anterior portion of the glabella and thus gives the genus its main aspect. Other parts unknown.

There is a considerable resemblance to *Lorenzella* Kobayashi, particularly because of the large neck ring and nuchal spine possessed by both. *Lorenzella* is merely a narrow *Inouyia,* and is also narrower than *Inouyops,* lacking the real differentiation of preglabellar area and rim.

Genotype.—Ptychoparia titiana Walcott.

Inouyops titiana (Walcott)

Ptychoparia titiana Walcott, Proc. U. S. Nat. Mus., vol. 29, p. 81, 1905.

Inouyia titiana Walcott, Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 155, pl. 14, fig. 9, 1913.

Middle Cambrian, Changhia; (loc. C7) 2 miles southwest of Yen-chuang, Shantung, China.

Holotype.—U.S.N.M. No. 58015.

Inouyops inflata (Walcott)

Ptychoparia inflata Walcott, Proc. U. S. Nat. Mus., vol. 30, p. 587, 1906.

Inouyia ? inflata Walcott, Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 152, pl. 14, fig. 10, 1913.

Lorenzella inflata Kobayashi, Journ. Fac. Sci. Imp. Univ. Tokyo, sect. 2, vol. 4, pt. 2, p. 254, 1935.

This species is placed in *Inouyops* although it differs from *I. titiana* in an important respect. Glabella, neck ring, and fixigenes agree closely. On the other hand, the brim is simple, consisting only of a strongly convex band without a rim. However, at the anterior angles faint traces of an anterior furrow may be seen, and so it is thought that the departure is merely due to obsolescence.

Middle Cambrian, Changhia; (loc. C69) 4 miles east of Fang-lan-chön, Shansi, China.

Holotype.—U.S.N.M. No. 58016.

KAOLISHANIA Sun, 1924

Kaolishania hopeiensis, new species

Kaolishania pustulosa Sun, Geol. Surv. China, Pal. Sinica, ser. B, vol. 7, fasc. 2, p. 59, pl. 2, figs. 25-29, 1935.

Sun's figures leave much to be desired, but it is apparent that *K. hopeiensis* is characterized by a short cranidium and a narrow pygidium. The cranidium has a straight anterior outline, and the glabella is marked by the usual furrows. The pygidial axis is long, rather strongly tapered, and the rear margin is strongly curved, with the large spines set farther forward than in *K. pustulosa.*

Upper Cambrian, Wolungshan, Huolu, Hopei, China.

Cotypes.—Tsing Hua Univ. Nos. S1161, S1164; Nat. Peiping Univ. No. S1165.

KINGSTONIA Walcott, 1924

Kingstonia thea (Walcott)

Agraulos ? thea Walcott, Proc. U. S. Nat. Mus., vol. 13, p. 277, pl. 21, fig. 15, 1890.

Pagodia thea Walcott, Smithsonian Misc. Coll., vol. 57, No. 13, p. 358, 1914; ibid., vol. 64, No. 3, pl. 37, 1916.

Komaspidella thea Kobayashi, Jap. Journ. Geol. and Geogr., vol. 15, Nos. 3, 4, p. 175, 1938.

In spite of its great abundance at many localities this species has never been adequately illustrated, and, strangely enough, apparently was not contained in the collections available to Hall in 1863. Walcott figured the cranidium in 1890, but disregarded several pygidia that lie within an inch of it, and again in 1916 designated only cranidia on the very fossiliferous slab then illustrated. In 1914 Walcott merely changed the generic assignment in faunal lists. Recently Kobayashi gave this species a new generic assignment which was unnecessary as will be explained below.

Kingstonia has been studied in recent months during description of many new species. Hitherto observers failed to note that the Wisconsin specimens are internal casts and consequently that they do not have the true aspect of their respective genera, for this mode of preservation always exaggerates the furrows. In fact, in *K. thea* it is likely that the test of both shields would show only a trace of the dorsal furrows. Among the many species now being described from North America, examples of complete shields occur together with partially or completely exfoliated examples. This condition of preservation is found not only in *Kingstonia* but also in *Bynumia* and other closely allied genera. From studies it is clear that *Agraulos? thea* is a *Kingstonia.*

Some doubt exists respecting the type locality. In 1890 Walcott gave it as Osceola Mills, but the specimens are labeled as coming from Eau Claire. It may be assumed that the latter is the type locality.

Upper Cambrian, Eau Claire; (loc. 78a) Eau Claire, and many other localities in Wisconsin.

Holotype.—U.S.N.M. No. 23864; plesiotypes on No. 61737.

Kingstonia seelyi (Walcott)

Pagodia seelyi Walcott, Smithsonian Misc. Coll., vol. 57, No. 9, p. 269, pl. 44, figs. 12-14a, 1912.

Lloydia seelyi Raymond (part), Proc. Boston Soc. Nat. Hist., vol. 37, No. 4, p. 410, 1924.

Upper Cambrian, Potsdam; (locs. 136, 136a) near Port Henry, Essex County, New York.

Cotypes.—U.S.N.M. Nos. 58582-58584.

KOOTENIA Walcott, 1888

Kootenia burgessensis, new species

Kootenia dawsoni Walcott, Smithsonian Misc. Coll., vol. 67, No. 4, p. 131, pl. 14, figs. 2, 3; 1918.

Neolenus serratus Walcott (part), idem, p. 126, pl. 36, fig. 3, 1918.

This species was identified with *K. dawsoni,* but differs considerably from that species. *K. burgessensis* has a quadrangular glabella, only slightly rounded in front. Fixigenes are slightly less than half the width of the glabella, and the libragenes have genal spines which reach back to about the third segment. In the pygidium the distinctive characteristic of the species is found in the six wide, rapidly tapering marginal spines. They separate the species from *K. dawsoni,* which has longer, much narrower spines.

Middle Cambrian, Burgess shale; (loc. 35k) Burgess Pass, near Field, British Columbia.

Holotype.—U.S.N.M. No. 65511; paratypes, Nos. 65512, 65533.

Kootenia slatkowskii (Schmidt)

Proetus (Phaeton) slatkowskii Schmidt, Bull. Acad. Imp. Sci. St. Petersburg, vol. 30, p. 418, figs. 11-14, 1886.

Dorypyge slatkowskii von Toll, Mem. Acad. Imp. Sci. St. Petersburg, ser. 8, vol. 8, No. 10, p. 33, pl. 2, figs. 1-10, 1899; Lermontova, Bull. Com. Geol. Leningrad, vol. 43, No. 9, p. 1105, pl. 17, figs. 1-12, 1926.

Middle Cambrian, Torgoshino limestone; Jenissei River, Siberia.

Cotypes and plesiotypes.—Leningrad.

Kootenia reticulata (Cobbold)

Dorypyge reticulata Cobbold, Quart. Journ. Geol. Soc. London, vol. 69, p. 33, pl. 3, figs. 1-15, 1913; Lake, Mon. British Cambr. Tril. Pal. Soc., pt. 11, p. 257, pl. 37, figs. 1-12, 1938.

Middle Cambrian, breccia bed of Upper Comley sandstone, Comley, Shropshire, England.

Holotypes and paratypes.—Sedgwick Mus. Cambridge Nos. A4446, A180-189.

Kootenia lakei (Cobbold)

Dorypyge lakei Cobbold, Quart. Journ. Geol. Soc. London, vol. 67, p. 287, pl. 25, figs. 1-8, text fig., 1911; ibid., vol. 87, p. 470, pl. 40, fig. 3, 1931; Cobbold and Pocock, Phil. Trans. Roy. Soc. London, ser. B, vol. 223, p. 373, 1934; Lake, Mon. British Cambr. Tril. Pal. Soc., pt. 11, p. 255, pl. 36, figs. 2-12, 1938.

Middle Cambrian, *Paradoxides groomi* grits; Comley and Rushton, Shropshire, England.

Holotype and paratypes.—Sedgwick Mus. Cambridge Nos. A66-70.

Kootenia valida (Matthew)

Dorypyge quadriceps valida MATTHEW, Trans. Roy. Soc. Canada, ser. 2, vol. 3, sect. 4, p. 189, pl. 4, figs. 2c, d, 1897.

Middle Cambrian, St. John 1d3; Hastings Cove, New Brunswick.

Holotype.—Roy. Ontario Mus. No. 8413.

LIOPARIA Lorenz, 1906

Lioparia burea (Walcott)

Ptychoparia (Proampyx) burea WALCOTT, Proc. U. S. Nat. Mus., vol. 29, p. 86, 1905.

Proampyx burea WALCOTT, Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 145, pl. 14, fig. 3, 1913.

When the holotype of *Proampyx burea* is carefully examined, it clearly falls within this genus. In the illustrated holotype the elevated central portion of the brim was carried away by the matrix.

Upper Cambrian, Tawenkou (*Chuangia* zone); (loc. C61) southwest of Yenchuang, Shantung, China.

Holotype.—U.S.N.M. No. 58001.

LISANIA Walcott, 1911

Lisania (?) tellus (Walcott)

Ptychoparia tellus WALCOTT, Proc. U. S. Nat. Mus., vol. 29, p. 80, 1905.

Lonchocephalus tellus WALCOTT, Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 143, pl. 14, fig. 1, 1913.

Middle Cambrian, Changhia; (loc. C2) 2 miles south of Yenchuang, Shantung, China.

Holotype.—U.S.N.M. No. 57997.

MANCHURIELLA Resser and Endo, 1931

Manchuriella yohi (Sun)

Ptychoparia yohi SUN, Geol. Surv. China, Pal. Sinica, ser. B, vol. 1, fasc. 4, p. 42, pl. 2, fig. 12, 1924.

Lower Cambrian, Manto; Chengshan, Chaokouchuang, Hopei, China.

Holotype.—Geol. Surv. China No. 535.

Manchuriella? leichuangensis (Sun)

Ptychoparia leichuangensis SUN, Geol. Surv. China, Pal. Sinica, ser. B, vol. 1, fasc. 4, p. 41, pl. 2, figs. 11a, b, 1924.

Lower Cambrian, Manto; Leichuang, Luanchou, Chihli, China.

Cotypes.—Geol. Surv. China Nos. 533, 534.

Manchuriella impar (Walcott)

Ptychoparia impar Walcott, Proc. U. S. Nat. Mus., vol. 29, p. 78, 1905; Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 131, pl. 12, figs. 9, 9a, 1913.

Lower Cambrian, Manto; (loc. C17) Changhia, Shantung, China.

Holotype and paratype.—U.S.N.M. Nos. 57950, 57951.

Manchuriella yenchouensis, new name

Ptychoparia impar var. Walcott, Proc. U. S. Nat. Mus., vol. 29, p. 79, 1905; Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 132, pl. 12, fig. 10, 1913.

Middle Cambrian, Changhia; (loc. C8), Yenchuang, Shantung, China.

Holotype.—U.S.N.M. No. 57952.

Manchuriella shantungensis, new species

Anomocare minus Walcott (part), Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 192, pl. 19, fig. 1, 1913 (not figs. 1a, 1b = genotype; *M. typa,* figs. 1c, 1d = *Prosaphiscus yabei*).

Manchuriella mina Resser and Endo, Manchurian Sci. Mus. Bull. 1, pt. 2, p. 242, pl. 36, fig. 2, 1937.

This species is typical of *Manchuriella,* but has a rather wide brim. Glabellar furrows very faint. Eyes situated about midpoint of glabella.

Middle Cambrian, Changhia; (loc. C9) 3 miles southwest of Yenchuang, Shantung, China.

Holotype.—U.S.N.M. No. 58156.

Manchuriella gerardi (Sun)

Conokephalina gerardi Sun, Geol. Surv. China, Pal. Sinica, ser. B, vol. 1, fasc. 4, p. 48, pl. 3, figs. 5a-c, 1924.

Lower Cambrian, Manto; Chengshan, Kaiping basin, Hopei, China.

Cotypes.—Geol. Surv. China Nos. 552-554.

MANSUYIA Sun, 1924

Mansuyia Sun, Geol. Surv. China, Pal. Sinica, ser. B, vol. 1, fasc. 4, p. 50, 1924; ibid., vol. 7, fasc. 2, p. 57, 1935; Kobayashi, Journ. Fac. Sci. Imp. Univ. Tokyo, sect. 2, vol. 4, pt. 2, p. 302, 1935; Journ. Geol. Soc. Japan, vol. 45, No. 534, p. 323, 1938.

This genus has a somewhat uncertain status because of the indefinite meaning of the genotype. Kobayashi (1938) recently called attention to the problem without offering a solution. All discussions of *Mansuyia* state that the genus is based on *M. orientalis.* Therefore, if the species *orientalis* is precisely determined, the genus will likewise gain a precise legal status. Our problem then becomes the determination of the specimens on which *M. orientalis* is rightfully based, and these will in turn give the characterization of the genus *Mansuyia.*

In 1924 Sun described *Mansuyia* by comparing the cranidium with *Crepicephalus* and the pygidium with *Anomocare, Anomocarella,* and *Ceratopyge.* He further stated that

> this genus is characterized by its short oblong glabella, narrow fixed cheeks, and absence of the palpebral ridge. The pygidium has two inward-curving slender lateral spines which spring out from the second segment of the pleural lobe of the pygidium.

He designated the genotype as *Mansuyia orientalis* (Grabau) Sun.

Mansuyia orientalis is described on page 50, immediately after the generic presentation. Reading of the description raises no questions, as all seems to be clear and straightforward. On the other hand, examination of the bibliographic references, the locality and the plate descriptions, raises serious problems. Further complications arise from the fact that the seven illustrated specimens represent two genera and at least three species.

First is the question of the author of the species. In his bibliography Sun cites as the first reference: "1922 *Ceratypyge orientalis* Grabau (Mss)." This evidently means that in 1922 Grabau attached this name to some undescribed specimens in the collections. The next reference reads: "1923 *Ceratopyge orientalis* Sun. Upper Cambrian of Kaiping Basin. Bulletin of the Geological Society of China, vol. 2, No. 1-2, p. 98 (listed)." From this it is apparent that neither reference is a description of the species, hence *Ceratopyge orientalis* Grabau is a nomen nudem, and the first valid use of the name is *Mansuyia orientalis* Sun, 1924. In 1935 Sun ascribed the species to himself as author.

Next arises the question as to which specimens are *M. orientalis.* The locality description leads one to the assumption that the types of the species come from Shantung. This is a natural inference because the words "also found in Chihli" are used to introduce the citation of the second locality. Likewise the plate descriptions leave the same impression. However, in the plate description the first five specimens from Shantung are called "cotypes," and the remaining two (figs. 7i, j) from Chihli, "types of *Ceratopyge orientalis* Grabau." From the bibliographic citations it is evident that Sun regarded the pygidia to which Grabau attached the manuscript name as the types of the species and his "cotypes" are paratypes. This is conclusively shown to be a fact by the statement Sun made in 1935. The initial sentence of the revised description of *Mansuyia* reads: "This genus was founded by myself based upon several pygidia of the *Ceratopyge* type and several associated cranidia which are now referred to another distinct genus *Taishania*." Therefore, it is clear that *Mansuyia* rests on *M. orientalis* Sun, which in turn is based on two pygidia from the Fengshan limestone, Yehli, Kaiping basin, Chihli, bearing the numbers G. S. C. 563, 564.

Great confusion was introduced in the 1935 report by reference of *all* specimens of *M. orientalis* on one page to *Taishania taianensis,* and on other pages, figures 7f-h to *M. orientalis;* figures 7i, j, the types of *M. orientalis,* which is a good species from Shantung, to *M. tani.* However, none of this affects the status of the genus and its type species.

Mansuyia orientalis (Sun)

Mansuyia orientalis Sun (part), Geol. Surv. China, Pal. Sinica, ser. B, vol. 1, fasc. 4, p. 50, pl. 3, figs. 7i, 7j, 1924.

Thus far no forms conspecific with the cotypes have been illustrated, hence the species rests solely on the original types. Below will be found references of other forms erroneously referred to the species.

Upper Cambrian, Fengshan; Yehli, Kaiping basin, Chihli, China.

Cotypes.—Geol. Surv. China Nos. 563, 564.

Mansuyia endoi, new name

Mansuyia orientalis Sun (part), Geol. Surv. China, ser. B, vol. 1, fasc. 4, p. 50, pl. 3, figs. 7a-7d, 1924; Endo, Jubilee Publ. Comm. Prof. Yabe's 60th Birthday, p. 11, pl. 2, figs. 13-20, 1939.

Upper Cambrian, Kaolishan; Kaolishan, Taian, Shantung, China.

Cotypes.—Geol. Surv. China Nos. 556-559; plesiotypes, Manchoukuo Sci. Mus.

MARYVILLIA Walcott, 1916

Maryvillia Walcott, Smithsonian Misc. Coll., vol. 64, No. 5, p. 400, 1916.

Ever since *Maryvillia* was described it has been necessary to exercise arbitrary selection of pygidia for almost every species, and the selection became increasingly difficult as the number of species increased. No trouble arose concerning the cranidia, but the pygidia became less and less distinguishable from *Blountia* and *Kingstonia.* Recent study of the species of the *Coosia* group led to recognition of a new genus for a series of trilobites, clearly related to *Coosia,* but which do not fit into described genera. As the work progressed the proposed genus in turn became unsatisfactory. Finally it became clear that pygidia, congeneric with that originally assigned to *Maryvillia arion,* fall into *Blountia,* where they fit well. *Maryvillia* may then be reconstructed on the basis of cranidial structure and the associated pygidium of *Coosia* affinities assigned to it. Unfortunately this necessitates change in nomenclature of Appalachian and other described species. On the other hand, a large number of other species become clear, *Maryvillia* receiving certain species of the *Coosia* group, thereby relieving pressure at that point.

A new diagnosis of *Maryvillia* should be written to lay greater emphasis on the cranidial characters and to add those of the pygidium now assigned to the genus.

The slightly tapering glabella is large, occupying two-thirds or more of the cranidial length and over half the width. It lacks furrows, only the faintest shadows showing on exfoliated specimens. The narrow dorsal furrow is shallow, but visible in all species, and it rounds off the anterior end of the glabella. Fixigenes less than half the glabellar width; of nearly even width throughout. Anterior facial suture diverges slightly and back of the eye develops posterolateral limbs about equal in width to the fixigenes. Eyes small, situated about the midpoint of cranidium. Eye lines present on exfoliated specimens. Brim simple, concave, with a flat rim differentiated by a shallow anterior furrow produced mainly by change in slope. On exfoliated specimens the preglabellar area is apt to be more strongly convex, which serves to accentuate the anterior furrow.

Pygidium rather large, nearly semicircular in outline with a well-defined axis, usually rising high above the pleural lobes. Fusion has nearly eliminated the axial furrows, and on the test almost all of the pleural grooves and furrows, except the anterior pair. Most species have a postaxial ridge that becomes more prominent on exfoliated examples. As a whole, the pygidium is generally more strongly convex than the cranidium. From this it may be inferred that the libragenes likely had a nearly vertical position, or that they were very convex in themselves.

Genotype.—*M. arion* Walcott (restricted).

The cranidia of *M. arion* are all exfoliated examples. An undescribed pygidium associated with the illustrated cranidia has been selected as representative of the species, and the pygidia originally referred to *M. arion* are now regarded as belonging to *Blountia.*

M. triangularis Raymond has a doubtful status. It certainly does not belong to *Maryvillia,* and it is questionable whether it belongs to *Blountia.*

Valid species of *Maryvillia* include

Maryvillia arion Walcott (restricted)
M. ariston Walcott (restricted)
M. bristolensis Resser
M. keithi Resser
M. virginica Resser
M. widnerensis Resser

Maryvillia arion Walcott (restricted)

Maryvillia arion WALCOTT (part), Smithsonian Misc. Coll., vol. 64, No. 5, p. 400, pl. 64, figs. 4, 4b, 1916.
Blountia alethes WALCOTT (part), idem, p. 397, pl. 64, figs. 1b, 1c, 1916.
Coosia alethes RESSER (part), Geol. Soc. Amer. Spec. Pap. 15, p. 71, pl. 13, fig. 10, 1938.

This species, which is the genotype, has been restricted (as far as the original types are concerned) to the cranidium. The pygidium formerly assigned to *Blountia alethes* coming from the same locality as the cranidia, is like the pygidia associated regularly with the *Maryvillia* head in other areas, for which reason it is now reassigned to this species. Walcott's figure was retouched erroneously.

Upper Cambrian, Nolichucky; (loc. 123b) ½ mile east of Rogersville, Tennessee.

Holotype.—U.S.N.M. No. 62826; plesiotypes, No. 62822.

Maryvillia ariston Walcott

Maryvillia ariston WALCOTT (part), Smithsonian Misc. Coll., vol. 64, No. 5, p. 401, pl. 64, fig. 5, 1916; RESSER (part), Geol. Soc. Amer. Spec. Pap. 15, p. 87, pl. 13, figs. 2, 3, 5, 1938.
Asaphiscus? sp. WALCOTT, Smithsonian Misc. Coll. vol. 64, No. 5, p. 391, pl. 63, figs. 3, 3a, 1916.

This species, like *M. arion,* is restricted to the cranidia, but search through the material in hand revealed the presence of three typical pygidia.

Upper Cambrian, Nolichucky; (locs. 119, 120, 197c) Copper Ridge, 11 and 14 miles northwest of Knoxville, Tennessee.

Holotype.—U.S.N.M. No, 62829; plesiotypes, Nos. 94997, 62810.

Maryvillia masadensis Resser (restricted)

Maryvillia masadensis RESSER (part), Geol. Soc. Amer. Spec. Pap. 15, p. 88, pl. 12, fig. 39, 1938.

Several excellent pygidia were discovered in the material from loc. 35s, and a narrow libragene, by its proportions and striated rim seems also to represent the species. If this is a correct reference it is the first libragene discovered for *Maryvillia.* It bears a long genal spine.

Upper Cambrian, Nolichucky; (loc. 22n) Widner Branch, 1½ miles southwest of Masada, and (loc. 35s) 4 miles northeast of Abingdon, Virginia.

Holotype.—U.S.N.M. No. 94964; plesiotypes, No. 102317.

Maryvillia georgica Resser (restricted)

Maryvillia georgica Resser (part), Geol. Soc. Amer. Spec. Pap. 15, p. 88, pl. 12, fig. 41, 1938.

A number of cranidia are in hand but only one imperfect pygidium has been found.

Upper Cambrian, Nolichucky; (loc. 96x) 1 mile north of Adairsville, Georgia.

Holotype.—U.S.N.M. No. 94966.

MEGALOPHTHALMUS Lorenz, 1906

Megalophthalmus shansiensis Resser

Ptychoparia (Liostracus) megalurus Walcott, Proc. U. S. Nat. Mus., vol. 29, p. 9, 1905.

Anomocare megalurus Walcott (part), Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 192, pl. 18, figs. 9-9d, 1913.

Middle Cambrian, Changhia; (loc. C37) 8 miles south of Tinghianghién, Shansi, China.

Cotypes.—U.S.N.M. Nos. 58147-58151.

OLENOIDES Meek, 1877

Olenoides constans Walcott

Neolenus constans Walcott, Smithsonian Misc. Coll., vol. 67, No. 2, p. 45, pl. 6, figs. 7, 7a, 1917.

This species belongs to the group which bridges the gap between *Olenoides* and *Kootenia,* a condition brought about by the degree of pygidial fusion.

Middle Cambrian, Ptarmigan; (loc. 63b) east base of Ptarmigan Peak, 6 miles east of Lake Louise, Alberta.

Holotype.—U.S.N.M. No. 63748.

Olenoides damia (Walcott)

Dorypygia damia Walcott, Smithsonian Misc. Coll., vol. 67, No. 3, p. 102, pl. 11, figs. 7, 7a, 1917.

Middle Cambrian, Ptarmigan; (loc. 62w) Gog Lake, below Wonder Pass, 19 miles southwest of Banff, British Columbia.

Lectotype.—U.S.N.M. No. 64375; paratypes, No. 64374.

Olenoides superbus (Walcott)

Neolenus superbus Walcott (part), Smithsonian Misc. Coll., vol. 53, No. 2, p. 36, pl. 4, figs. 1, 5, 1908.

Neolenus intermedius pugio WALCOTT (part), idem, p. 35, pl. 6, fig. 8, 1908.
Olenoides superbus KOBAYASHI, Journ. Fac. Sci. Imp. Univ. Tokyo, sect. 2, vol. 4, pt. 2, p. 154, 1935.

The numerous species in the Marjum formation are being more precisely discriminated. This necessitates rearrangement of the specimens and assignment of new names to some. *O. inflatus* needs no modification, but *O. superbus* must be restricted.

Middle Cambrian, Marjum; (loc. 11q) Antelope Springs, House Range, Utah.

Lectotype.—U.S.N.M. No. 53383; paratypes, Nos. 53380, 53400.

Olenoides intermedius (Walcott)

Neolenus intermedius WALCOTT (part), Smithsonian Misc. Coll., vol. 53, No. 2, p. 34, pl. 6, figs. 1-3, 1908.
Neolenus superbus WALCOTT (part), idem, p. 36, pl. 4, fig. 3, 1908.
Olenoides intermedius KOBAYASHI, Journ. Fac. Sci. Imp. Univ. Tokyo, sect. 2, vol. 4, pt. 2, p. 154, 1935.

Occurrence same as preceding.

Lectotype.—U.S.N.M. No. 53394; paratypes, Nos. 53384, 53397, 53398.

Olenoides pugio (Walcott)

Neolenus intermedius pugio WALCOTT (part), Smithsonian Misc. Coll., vol. 53, No. 2, p. 35, pl. 6, fig. 9, 1908.
Neolenus intermedius WALCOTT (part) idem, p. 34, pl. 6, fig. 7, 1908.
Olenoides pugio KOBAYASHI, Journ. Fac. Sci. Imp. Univ. Tokyo, sect. 2, vol. 4, pt. 2, p. 154, 1935.

Occurrence same as preceding.

Holotype.—U.S.N.M. No. 53401; plesiotype, No. 53393.

Olenoides marjumensis, new species

Neolenus intermedius WALCOTT (part), Smithsonian Misc. Coll., vol. 53, No. 2, p. 34, pl. 6, figs. 4, 5, 1908.

Walcott noted the fact that this form has six pygidial spines and regarded it as a doubtful example of *O. intermedius*.

The long, slightly extended glabella protrudes considerably beyond the anterior angles. Four pairs of glabellar furrows show faintly. A short occipital spine is present. Longitudinally the glabella is only slightly arched and not at all swollen. Its cross section has low convexity, rather flattened on top, and with a faint keel showing in cross light. Fixigenes at the eyes are less than one-third the glabellar width. Surface covered with the usual lines, in this instance not developed as scales.

The holotype pygidium has six pairs of marginal spines, but evidently lacks axial spines.

Occurrence same as preceding.

Holotypes.—U.S.N.M. No. 53392; paratype, No. 53395.

Olenoides housensis, new species

Neolenus superbus Walcott (part), Smithsonian Misc. Coll., vol. 53, No. 2, p. 36, pl. 4, fig. 4, 1908.

A single small cranidium with a protuberant glabella was referred to *O. superbus.* It resembles that species, but *O. marjumensis* even more. However, since its glabella is relatively shorter, a new species must be provided for it.

The glabella is very large and protrudes beyond the anterior angles with an evenly curved outline. Glabellar furrows are exceedingly faint. Occipital furrow strong; occipital ring swollen and extends into a heavy spine of unknown length. Fixigenes at anterior end of eyes reduced to little more than the width of the eye band. Surface lined vertically in the usual manner.

Occurrence same as preceding.

Holotype.—U.S.N.M. No. 53382.

Olenoides decorus, new species

Neolenus intermedius Walcott (part), Smithsonian Misc. Coll., vol. 53, No. 2, p. 34, pl. 6, fig. 6, 1908.

A small cranidium figured by Walcott was noted to differ from the other cranidia of *O. intermedius.*

The glabella, rounded in front, extends slightly beyond the anterior angles. A rear pair of furrows shows faintly. The occipital ring is swollen and has a short, stout spine. Longitudinally the head is only slightly convex, and the glabella is also rather flat in cross section.

A four-spined pygidium is assigned to the species.

Middle Cambrian, Marjum; (loc. 3x) 2½ miles east of Antelope Springs, House Range, Utah.

Holotype.—U.S.N.M. No. 53396.

Olenoides horridus (Matthew)

Dorypyge horrida Matthew, Trans. Roy. Soc. Canada, ser. 2, vol. 3, sect. 4, p. 190, pl. 4, figs. 3a, b, 1897.

Middle Cambrian, St. John 1d3; Hastings Cove, New Brunswick, Canada.

Holotype.—Roy. Ontario Mus. No. 8410.

Olenoides acadicus (Matthew)

Dorypyge wasatchensis acadica Matthew, Trans. Roy. Soc. Canada, ser. 2, vol. 3, sect. 4, p. 188, pl. 4, fig. 1, 1897.

Middle Cambrian, St. John 1d3; Hastings Cove, New Brunswick, Canada.

Holotype.—Roy. Ontario Mus.

ORYGMASPIS Resser, 1937

Orygmaspis weedi, new species

Ptychoparia (?) sp. undet. Walcott, U. S. Geol. Surv. Monogr. 32, p. 458, pl. 66, fig. 3, 1899.

Walcott recognized the relationships of this species, in the text referring it to *O. eryon* and subsequently labeling the specimens as that species. *O. weedi* occurs in crystalline limestone surfaces on thin vaughnite layers, and is represented by several cranidia on the two pieces of rock in the collections. In addition there are several libragenes and one pygidium. This species resembles *O. eryon,* but is relatively shorter and has a deeper anterior furrow, which thus defines the rim more clearly. The outer surface appears to be smooth, but large exfoliated specimens have anastomosing lines on the preglabellar area, becoming strongest toward the anterior angles. Likewise on the ocular platforms of the libragenes, similar lines radiate from the eyes. The pygidium has a high axis and gently convex pleural lobes on which both the pleural grooves and furrows are clearly indicated.

Upper Cambrian, Dry Creek; Crowfoot Ridge, Yellowstone National Park, Montana.

Holotype.—U.S.N.M. No. 102318.

PAGETIA Walcott, 1916

Pagetia orientalis (Walcott)

Microdiscus orientalis Walcott, Proc. U. S. Nat. Mus., vol. 29, p. 24, 1905; Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 102, pl. 7, fig. 10, 1913.

Middle Cambrian, Kisingling; (loc. C32) Drift, Nanho, 1 mile south of Chonping, Shensi, China.

Holotype.—U.S.N.M. No. 57844.

PARAMANSUYELLA Endo, 1937

Paramansuyella taianensis, new species

Mansuyia orientalis SUN, Geol. Surv. China, Pal. Sinica, ser. B, vol. 7, fasc. 2, p. 58, pl. 2, figs. 20-24, 1935.

This species is characterized by the width of the pygidium and the divergence of the pygidial spines. The brim is stout and simple, and the eyes of normal size and position.

Upper Cambrian, Tawenkou; Tawenkou, Taian, China.

Cotypes.—Tsing Hua Univ. Nos. S1156-S1160.

PEISHANIA Resser and Endo, 1935

Peishania talignensis (Dames)

Liostracus talingensis DAMES, von Richthofen's China, vol. 4, p. 19, pl. 1, fig. 20, 1883.

Ptychoparia talingensis KOBAYASHI, Journ. Geol. Soc. Japan, vol. 44, No. 524, p. 432, pl. 17, fig. 11, 1937.

Middle Cambrian, Taitzu; Taling, south of Hsiaoshih, Liau-tung, Manchoukuo.

Holotype.—Natur. Mus. Berlin.

PERIOURA Resser, 1938

Perioura is now identified in the Cordilleran region, and thus affords another point of correlation with the Appalachians. Late Middle Cambrian fossils are just becoming known, although several sizeable faunas are described. This genus includes *Mcnairia* Deiss.

Perioura inornata (Deiss)

Mcnairia inornata DEISS, Geol. Soc. Amer. Spec. Pap. 18, p. 104, pl. 17, figs. 27-30, 1939.

Middle Cambrian, Steamboat; Cliff Mountain, Chinese Wall, Lewis and Clark Range, Montana.

Holotype.—Montana Univ. No. T1140; paratype, No. T1141.

Perioura callas (Walcott)

Marjumia callas WALCOTT, Smithsonian Misc. Coll., vol. 64, No. 5, p. 402, pl. 65, figs. 3-3b, 1916.

Middle Cambrian, Marjum; (loc. 31r) 1 mile southeast of Marjum Pass, House Range, Utah.

Holotype.—U.S.N.M. No. 62839; paratypes, Nos. 62840, 62841.

PHYLACTERUS Raymond, 1924

Phylacterus welleri (Raymond)

Microdiscus ? sp. undet. WELLER, Geol. Surv. New Jersey, Pal., vol. 3, p. 114, pl. 3, fig. 11, 1903.

Pseudosalteria welleri RAYMOND, Proc. Boston Soc. Nat. Hist., vol. 37, No. 4, p. 399, 1924.

Raymond judged the relationship of this trilobite from Weller's incomplete figure. Several specimens were collected by Dickhout in 1901 at Weller's locality. They all have a rim which evidently was lacking in the incomplete holotype. The presence of the rim places the species in *Phylacterus* rather than *Pseudosalteria.*

Upper Cambrian, Kittatinny; (loc. 11c) quarry at Newton, Essex County, New Jersey.

Holotype.—Geol. Surv. New Jersey.

PLATYCOLPUS Raymond, 1913

Platycolpus barabuensis (Winchell)

Ptychaspis barabuensis WINCHELL (part), Amer. Journ. Sci., vol. 37, p. 230, 1864.

Platycolpus barabuensis RAYMOND, Bull. Victoria Mus. vol. 1, p. 64, 1913.

This species has never been illustrated. It is a particularly interesting form because of its large size and early age. Winchell, however, had other forms mixed with it that have now been referred to other genera. In 1882 Whitfield described a *Platycolpus* species from the younger St. Lawrence (Mendota) dolomite, applying Winchell's name. Subsequently the St. Lawrence form became the basis of the concept of *P. barabuensis,* because it was illustrated and the original types were not. At the same time Whitfield named the large species in the Mendota dolomite *P. eatoni.* It happens that *P. eatoni* Whitfield and *P. barabuensis* Winchell resemble each other more than the *P. barabuensis* of Whitfield. There is one or more smaller species in the Franconia (Devils Lake) sandstone, and these forms resemble the small one to which Whitfield erroneously applied the name *barabuensis.* This confusion can easily be resolved by restricting the name *P. barabuensis* to the specimens among Winchell's types that belong to *Platycolpus,* and give the form described by Whitfield a new name.

As now constituted *P. barabuensis* is a large species, perhaps the largest yet found. Neither the cranidium nor the pygidium have as great convexity as the almost equally large *P. eatoni* from the St. Lawrence. Only the anterior half of a cranidium has been located in the collections in hand from the vicinity of the type locality. This cranidium has large prominent palpebral lobes which attain their prominence chiefly by the elevation of their rear extremities. The brim is wide, heavily striated, and set in a vertical position that makes it appear to be pressed back against the front of the glabella. A single fragment seems to indicate that the libragenes were large and long, as they are in *P. eatoni*. The pygidium is well represented both by the Winchell lectotype and by specimens in the National Museum collections. It is characterized by a wide, stout axis on which several segments are faintly outlined. Of course, it must be remembered that all these specimens in a coarse sandstone matrix are impressions of the underside of the test, so that all furrows are accentuated. If the outer surface of the test or an impression of it was preserved, the trilobite would appear much smoother and with almost no furrows. The axis stands above the pleural platforms. They in turn are little differentiated from the wide border.

Upper Cambrian, Franconia (Devils Lake); (loc. 81) 1 mile northeast of Devils Lake; and ¼ mile southeast of Woods Quarry, Baraboo, Wisconsin.

Lectotype.—Univ. Michigan No. 4879; cast, U.S.N.M. No. 102319.

Platycolpus whitfieldi, new species

Dikelocephalus barabuensis WHITFIELD, Ann. Rep. Geol. Surv. Wisconsin for 1877, p. 63, 1878; Geol. Wisconsin, vol. 4, p. 201, pl. 4, figs. 6-9, 1882.

When Whitfield described the species found in the St. Lawrence (Mendota) dolomite near Baraboo, he applied Winchell's name to a species of *Platycolpus*. As previously stated, this species is much smaller and otherwise distinct so that it must have a new name. While typical of the genus in all respects, *P. whitfieldi* is characteristic of a rather distinct group of species. The glabella is large, extending nearly the full length of the cranidium. Transversely the cranidium is moderately convex, but longitudinally it is more highly arched, particularly in its anterior half. The thickened rim stands vertically, and at its inner edge rises sharply above a very narrow preglabellar area. The rim is striated as usual. Narrow fixigenes remain immediately in front of the eyes. The occipital and the rear pair of glabellar furrows are visible. It is in the libragene that the greatest distinction is found when this species is compared with either *P. barabuensis* or *P. eatoni*. In this case the libragene constitutes nearly a quarter circle, hence is shorter than the others. It has a wide rim that is sharply curved to the genal angle, where a slight, blunt spine may be present. The pygidium is normal, with a rather rapidly tapering axis extending about two-thirds the length of the pygidium. As in the cranidium, several axial and pleural furrows are visible in the pygidium. The pleural platforms and the border constitute a convex area.

Upper Cambrian, St. Lawrence (Mendota); Eikey's Quarry, near Baraboo, Wisconsin.

Cotypes.—Univ. California No. 1214; cast, U.S.N.M. No. 98261.

PLETHOPELTIS Raymond, 1913

Plethopeltis saratogensis (Walcott)

Ptychoparia (Agraulos) saratogensis WALCOTT, U. S. Geol. Surv. Bull. 30, p. 21, 1886.

Agraulos saratogensis WALCOTT, Proc. U. S. Nat. Mus., vol. 13, p. 276, pl. 21, fig. 14, 1890; (part), Smithsonian Misc. Coll., vol. 57, No. 9, p. 269, pl. 43, figs. 11-13a, 15, 15a, 1912.

Plethopeltis saratogensis RAYMOND, Victoria Mem. Mus. Bull. 1, p. 64, 1913; Proc. Boston Soc. Nat. Hist., vol. 37, No. 4, p. 412, 1924.

Walcott failed to observe that his holotype is an exfoliated specimen. In spite of that fact it has no glabellar furrows, although faint impressions were put into the illustration. Some other specimens do show shallow furrows on exfoliated surfaces, but on the outside of the test even the dorsal furrow should be shallow. Fragments of test remaining indicate that the *P. saratogensis* had ornamentation, but it is not clear what its pattern is. The types are restricted to one species, but several others are found among the unfigured specimens.

Upper Cambrian, Potsdam (Hoyt member); (loc. 76) 4 miles west of Saratoga Springs, New York.

Holotype.—U.S.N.M. No. 23863 (58558); plesiotypes, Nos. 58559, 58560, 58562.

Plethopeltis walcotti Raymond

Plethopeltis walcotti RAYMOND, Proc. Boston Soc. Nat. Hist., vol. 37, No. 4, p. 414, pl. 12, figs. 20, 24, 1924.

Kaniniella? walcotti KOBAYASHI, Jap. Journ. Geol. and Geogr. vol. 15, Nos. 3, 4, p. 190, 1938.

It is a question whether Raymond did not found this species on the same form as *P. saratogensis,* since that species too has no glabellar furrows. This problem cannot be solved until the types can be compared.

Occurrence same as preceding.

Holotype.—M.C.Z. No. 1730; paratype, No. 1731.

Plethopeltis granulosa, new species

Ptychaspis speciosus WALCOTT (part), Smithsonian Misc. Coll., vol. 57, No. 9, p. 272, pl. 43, figs. 18, 18a, 1912.

Agraulos saratogensis WALCOTT (part), Smithsonian Misc. Coll., vol. 57, No. 9, p. 269, pl. 43, figs. 14, 14a, 1912.

The pygidium assigned by Walcott to the saukian trilobite he placed in *Ptychaspis speciosus* seems to belong with a cranidium lying near it in the matrix. A fragment of a *Saukia* pygidium lies near both. At first it was thought that this pygidium may represent *P. saratogensis,* even though it is granulose, but comparisons revealed that neither the head nor the tail is that species. One of the cranidia illustrated as *P. saratogensis* apparently is the same species as that lying near the pygidium. Thus constituted, the species has definite characteristics.

Size and shape are normal for both head and tail. The rear pair of furrows are rather deep, and a second pair is visible on the outer surface. The brim sets at a less steep angle to the horizontal than in *P. saratogensis,* and in itself is less convex. Eyes normal in size, situated slightly anterior to the midpoint of glabella. Surface of cranidium finely granulose; brim marked by strong striations roughly parallel to the front margin.

The pygidial axis is wide and long, and stands well above the convex pleural platforms. Axis strongly divided by furrows, and both pleural grooves and furrows are well developed. Surface granulose, and the steep border slope is striated like the brim.

Upper Cambrian, Potsdam (Hoyt member); (loc. 76) 4 miles west of Saratoga Springs, New York.

Holotype.—U.S.N.M. No. 58561; paratype, No. 58565.

PROASAPHISCUS Resser and Endo, 1935

Proasaphiscus eriopia (Walcott)

Anomocare eriopia Walcott, Proc. U. S. Nat. Mus., vol. 30, p. 582, 1906.
Ptychoparia (*Emmrichella*) *eriopia* Walcott, Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 136, pl. 13, figs. 4, 4a, 1931.

Even though the cranidium is incomplete, it seems that the species should be assigned to the same genus as *P. ephori.*

Middle Cambrian, Changhia; (loc. C23) 1 mile east-southeast of Changhia, Shantung, China,

Holotype.—U.S.N.M. No. 57970; paratype, No. 57971.

Proasaphiscus rectangularis (Sun)

Lisania rectangularis Sun, Geol. Surv. China, Pal. Sinica, ser. B, vol. 1, fasc. 4, p. 55, pl. 4, figs. 2a, b, 1924.

Middle Cambrian, Nanchuang; Chengshan, near Chaokouchuang, Chihli, China.

Cotypes.—Geol. Surv. China Nos. 575, 576.

PROBOWMANIA Kobayashi, 1935

Probowmania fongi (Sun)

Ptychoparia fongi Sun, Geol. Surv. China, Pal. Sinica, ser. B, vol. 1, fasc. 4, p. 40, pl. 2, figs. 10a, b, 1924.

Lower Cambrian, Manto; Chengshan, Chaokouchuang, Chihli, China.

Cotypes.—Geol. Surv. China Nos. 531, 532.

Probowmania granosa (Walcott)

Ptychoparia granulosa WALCOTT, Proc. U. S. Nat. Mus., vol. 29, p. 78, 1905.
Ptychoparia granosa WALCOTT, Smithsonian Misc. Coll., vol. 57, No. 4, p. 77, pl. 14, fig. 8, 1911; Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 131, pl. 12, fig. 7, 1913.

Lower Cambrian, Manto; (loc. C17) Changhia, Shantung, China.

Holotype.—U.S.N.M. No. 57602.

PROSAUKIA Ulrich and Resser, 1933

Prosaukia barabuensis, new species

Dicellocephalus pepinensis WINCHELL (part), Amer. Journ. Sci., vol. 37, p. 229, 1864 [head].
Dicellocephalus minnesotensis WINCHELL (part), idem. p. 229, 1864 [tail].
Ptychaspis barabuensis WINCHELL (part), idem, p. 230, 1864 [cheek].
Saukia crassimarginata ? WALCOTT (part), Smithsonian Misc. Coll., vol. 57, No. 13, p. 377, pl. 65, fig. 9, 1914.

Several pygidia are available, and libragenes described by Winchell seem to be referable to the species. The description of the species, therefore, is based on the pygidium, while the libragenes of Winchell are merely referred to it. This pygidium has a rather long and stout axis in which at least five rings are visible. The axis stands high above the pleural platforms and terminates in a pronounced postaxial ridge. The pleural platforms are small, in front equaling about the width of the axis, but tapering to extinction anterior to the end of the axis. Pleural grooves and furrows are strong, extending practically to the outer margins. The furrows subdivide the pleura subequally. The border is increasingly concave toward the rear, where the border width is about two-thirds the axial length.

Upper Cambrian, Franconia (Mazomanie member); (loc. 81b) near Devils Lake, Wisconsin.

Holotype.—U.S.N.M. No. 58626; paratypes, Univ. Michigan Nos. 21216, 21210, 21217.

Prosaukia newtonensis (Weller)

Dikelocephalus newtonensis WELLER, Geol. Surv. New Jersey, Pal., vol. 3, p. 121, pl. 3, figs. 1-7, 1903.
Calvinella newtonensis WALCOTT (part), Smithsonian Misc. Coll., vol. 57, No. 13, p. 389, pl. 70, figs. 7, 8, 11, 11a, 1914.

Upper Cambrian, Kittatinny; (loc. 11c) quarry near Newton, Sussex County, New Jersey.

Holotype and paratypes.—Geol. Surv. New Jersey.

Prosaukia welleri, new species

Calvinella newtonensis WALCOTT (part), Smithsonian Misc. Coll., vol. 57, No. 13, p. 389, pl. 70, figs. 9, 10, 1914.

Two of the specimens, a head and a libragene, from the same locality as *P. newtonensis,* were referred to that species by Walcott. Two other species still remain to be described, showing that the saukian trilobites were apparently as prolific in New Jersey as in Wisconsin.

P. welleri is characterized by its large size and the strongly ornamented surface. Granules cover the elevated parts of the cranidium. The neck spine is very short. On the libragene the granules are present only on the ridge immediately in front of the occipital furrow, and then pass into anastomosing lines, which run roughly parallel to the outer margin and cover the ocular platform.

Upper Cambrian, Kittatinny; (loc. 11c) quarry near Newton, Sussex County, New Jersey.

Holotype.—U.S.N.M. No. 58678; paratype, No. 58679.

Prosaukia tribulis (Walcott)

Dicellocephalus tribulis WALCOTT, Smithsonian Misc. Coll., vol. 57, No. 9, p. 274, pl. 44, figs. 8, 8a, 1912.

Dikelocephalus ? tribulis WALCOTT, ibid., No. 13, p. 372, pl. 63, figs. 8-10a, 1914.

It cannot now be determined whether this species is fully typical of the genus. One cannot be sure of certain details owing to the fact that the genotype and other upper Mississippi Valley species are exfoliated, while *P. tribulis* is represented by unexfoliated specimens in a limestone matrix.

Upper Cambrian, Potsdam (Hoyt member); (loc. 76) 4 miles west of Saratoga Springs, New York.

Holotype.—U.S.N.M. No. 58578; paratype, No. 58617.

PSILASPIS Resser and Endo, 1935

Psilaspis RESSER and ENDO, *in* Kobayashi, Journ. Fac. Sci. Imp. Univ. Tokyo, sect. 2, vol. 4, pt. 2, p. 286, 1935; Manchurian Sci. Mus. Bull. 1, pt. 2, p. 268, 1937.

Lioparella KOBAYASHI, Journ. Geol. Soc. Japan, vol. 44, No. 524, p. 429, 1937.

Psilaspis alcinoe (Walcott)

Anomocare alcinoe WALCOTT, Proc. U. S. Nat. Mus., vol. 29, p. 47, 1905; Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 187, pl. 18, figs. 6-6b, 1913.

Liostracus latus LORENZ, Deutsch. Geol. Ges. Zeitschr., vol. 58, No. 2, p. 81, pl. 5, fig. 15, 1906.

Middle Cambrian, Changhia; (loc. C57) Tungyü, south of Sintai, Shantung, China.

Holotype.—U.S.N.M. No. 58137; paratypes, Nos. 58138, 58139; plesiotypes, Freiburg in Br. Mus.

Psilaspis flava (Walcott)

Anomocare flava Walcott, Proc. U. S. Nat. Mus., vol. 30, p. 583, 1906; Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 190, pl. 18, figs. 8-8c, 1913.

Saimachia ? flava Kobayashi, Journ. Geol. Soc. Japan, vol. 44, No. 524, p. 430, 1937.

Middle Cambrian, Changhia; (loc. C72) Fang-lan-chön, Shansi.

Cotypes.—U.S.N.M. Nos. 58143, 58146.

Psilaspis blautoeides (Lorenz)

Lioparia blautoeides Lorenz, Deutsch. Geol. Ges. Zeitschr., vol. 58, p. 78, pl. 6, figs. 1-3, 1906; Kobayashi, Journ. Fac. Sci. Imp. Univ. Tokyo, sect. 2, vol. 4, pt. 2, p. 240, 1935.

Anomocarella baucis Walcott, Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 7, 1913.

Anomocare sp. undet. Walcott, idem, p. 194, pl. 19, fig. 5, 1913.

Middle Cambrian, Changhia; northern slopes of the Taishan, south of Tsi-nan-fu, Shantung, China.

Cotypes.—Freiburg Mus.; cast, U.S.N.M. No. 102321.

Psilaspis speciosa (Lorenz)

Anomocare speciosum Lorenz, Deutsch. Geol. Ges. Zeitschr. vol. 58, p. 77, pl. 5, figs. 6, 7, 1906.

Anomocarella speciosa Walcott, Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 205, pl. 20, fig. 8, 1913.

Anomocarella thraso Walcott (part), idem, p. 208, pl. 19, fig. 14a, 1913.

Anomocarella albion Walcott (part), idem, p. 195, pl. 20, fig. 1e, 1913.

Middle Cambrian, Changhia; Wang-chuang, east of Sintai; (loc. C7) 2 miles and (loc. C4) 3 miles southwest of Yenchou, Shantung, China.

Cotypes.—Freiburg Mus.; cast, U.S.N.M. No. 58540; plesiotypes, U.S.N.M. Nos. 58184, 58191.

Psilaspis suni, new species

Anomocare flava Sun, Geol. Surv. China, Pal. Sinica, ser. B, vol. 1, fasc. 4, p. 80, pl. 5, figs. 8-8c, 1924.

This species seems to be clearly referable to *Psilaspis,* even though the drawings illustrating it are rather poor. It certainly cannot be *P. flava,* although there is considerable resemblance. *P. suni* has a straighter anterior margin and a somewhat larger glabella. The pygidium likewise has a stouter axis.

Middle Cambrian, Nanchuang; 2 miles from Chaokouchuang, Kaiping basin, Chihli, China.

Cotypes.—Geol. Surv. China Nos. 619-622.

Psilaspis walcotti (Kobayashi)

Anomocare latelimbatum Walcott (part), Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 191, pl. 18, figs. 2d, 2e, 1913.
Lioparella walcotti Kobayashi, Journ. Geol. Soc. Japan, vol. 44, No. 524, p. 429, 1937.

Middle Cambrian, Changhia; (loc. C52) 3 miles northeast of Sin-tai-hien, Shantung, China.

Cotypes.—U.S.N.M. Nos. 58131, 58132.

Psilaspis baucis (Walcott)

Anomocarella baucis Walcott, Proc. U. S. Nat. Mus., vol. 29, p. 55, 1905; Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 196, pl. 20, figs. 2, 2a, 1913.

Upper Cambrian, Kaolishan; (loc. C36) near Chaumitien, Changhia district, Shantung, China.

Cotypes.—U.S.N.M. Nos. 58193, 58194.

Psilaspis contigua (Walcott)

Anomocarella contigua Walcott, Proc. U. S. Nat. Mus., vol. 30, p. 584, 1906.
Anomocarella albion Walcott (part), Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 195, pl. 20, figs. 1a-1d, 1913.

Since Walcott included two species in *P. albion,* it is desirable to resurrect the name *contigua,* which he suppressed.

Middle Cambrian, Changhia; (loc. C2) 2 miles south of Yen-chuang, Sintai district, Shantung, China.

Cotypes.—U.S.N.M. Nos. 58187-58190.

Psilaspis vesta (Walcott)

Ptychoparia vesta Walcott, Proc. U. S. Nat. Mus., vol. 30, p. 590, 1906.
Conokephalina vesta Walcott, Research in China, vol. 3, Carnegie Inst. Washington Publ, 54, p. 139, pl. 13, figs. 9-9b, 1913.

Middle Cambrian, Changhia; (loc. C69) 4 miles east of Fang-lan-chön, Shansi, China.

Cotypes.—U.S.N.M. Nos. 57974-57977.

Psilaspis albion Walcott

Anomocarella albion Walcott, Proc. U. S. Nat. Mus., vol. 29, p. 54, 1905; (part) Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 195, pl. 20, fig. 1, 1913.

Middle Cambrian, Changhia; (loc. C57) 4 miles north of Sintai, Shantung, China.

Holotype.—U.S.N.M. No. 58186.

Psilaspis decelus (Walcott)

Anomocare decelus Walcott, Proc. U. S. Nat. Mus., vol. 29, p. 52, 1905.

Coosia decelus Walcott, Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 212, pl. 21, fig. 8, 1913.

Middle Cambrian, Changhia (loc. C9) 3 miles southwest of Yenchuang, Sintai district, Shantung, China.

Holotype.—U.S.N.M. No. 58227.

Psilaspis bigsbyi (Walcott)

Anomocare bigsbyi Walcott, Proc. U. S. Nat. Mus., vol. 30, p. 581, 1906.

Anomocarella bigsbyi Walcott, Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 198, pl. 21, figs. 3-3b, 1913.

Middle Cambrian, Changhia; (loc. C71) 4 miles southwest of Tungyü, Shansi, China.

Cotypes.—U.S.N.M. Nos. 58219-58221.

Psilaspis butes (Walcott)

Anomocare (?) butes Walcott, Proc. U. S. Nat. Mus., vol. 29, p. 49, 1905.

Anomocarella butes Walcott, Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 199, pl. 19, figs. 7-7d, 1913.

Middle Cambrian, Changhia; (loc. C5) 3 miles southwest of Yenchuang; (loc. C52) 3 miles northeast of Sintai, Shantung, China.

Cotypes.—U.S.N.M. Nos. 58169-58172; plesiotype, No. 58168.

Psilaspis expansas (Kobayashi)

Lioparia expansus Kobayashi, Journ. Fac. Sci. Imp. Univ. Tokyo, sect. 2, vol. 4, pt. 2, p. 240, pl. 19, fig. 13, 1935.

Lioparella expansa Kobayashi, Journ. Geol. Soc. Japan, vol. 44, No. 524, p. 429, 1937.

Middle Cambrian, Taiki (*Solenoparia* zone); Doten, south Chosen.

Holotype.—Geol. Inst. Univ. Tokyo.

Psilaspis tatian (Walcott)

Anomocare tatian Walcott, Proc. U. S. Nat. Mus., vol. 29, p. 53, 1905.

Anomocarella tatian Walcott, Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 206, pl. 21, figs. 1-1b, 1913.

Middle Cambrian, Changhia; (loc. C23) 1 mile southeast of Changhia, Shantung, China.

Holotype.—U.S.N.M. No. 58198; paratypes, Nos. 58199, 58200.

PTYCHOPLEURITES Kobayashi, 1936

This genus is rare, although it occurs from Texas to the Canadian Rockies.

Ptychopleurites eurekensis (Kobayashi)

Richardsonella eurekensis Kobayashi, Jap. Journ. Geol. and Geogr., vol. 12, Nos. 3-4, p. 55, pl. 9, fig. 9, 1935.

Upper Cambrian, Hamburg; (loc. 25L) east of Hamburg Mine, Eureka district, Nevada.

Holotype.—U.S.N.M. No. 93052.

QUADRATICEPHALUS Sun, 1924

Quadraticephalus Sun, Geol. Surv. China, Pal. Sinica, ser. B, vol. 1, fasc. 4, p. 61, 1924; Kobayashi, Jap. Journ. Geol. and Geogr., vol. 11, Nos. 1, 2, p. 119, 1933.

Changia Sun, Geol. Surv. China, Pal. Sinica, ser. B, vol. 1, fasc. 4, p. 59-60, 1924.

Sun recognized the close similarity of *Changia chinensis* to *Quadraticephalus walcotti* but regarded their slight differences as of generic rank. He states that *Quadraticephalus*

> is similar to the genus *Chuangia* in form, but the presence of the median longitudinal ridge, subrectangular glabella with parallel sides and punctate character of the surface serves to distinguish it.

Sun evidently meant to write *Changia* and not *Chuangia.*

These distinguishing features are not of generic rank, but merely separate the species. Both species established as respective genotypes have essentially the same glabellar structure, the slight constriction of its sides in *Q. chinensis* being more an optical illusion produced by the increase in depth of furrows than an actuality. At any rate, differences of this feature to the degree shown in the species now known are never of more than specific importance. Likewise the presence or absence of a keel on the glabella, which otherwise is constructed on the same pattern, is only of specific value. Punctate structure of the trilobite test is rarely found on the outer surface of Cambrian species. On the other hand, almost any species that has broad unfurrowed surfaces will show punctate structure when preserved in a certain fashion. Punctation most often appears when the fossil is an impression of the under side of the test. At other times this feature is conspicuous when one or more layers of the test are peeled off so that the surface of the fossil is composed of a test layer below its outer surface. All the specimens of *Quadraticephalus* in our collections show the punctation only when the outer layers of the test are peeled off.

Quadraticephalus is chosen as the name to be retained, in spite of its length, because *Changia* is similar and easily confused with *Chuangia* and *Changhia,* both well-established genera. Moreover, *Quadraticephalus* is much better known and its use more widely spread in literature than *Changia*.

Changia chinensis Sun and *C. shakoutunensis* Sun both become *Quadraticephalus*.

Genotype.—*Q. walcotti* Sun.

Quadraticephalus bianos (Walcott)

Anomocare bianos WALCOTT, Proc. U. S. Nat. Mus., vol. 29, p. 48, 1905.

Coosia ? bianos WALCOTT, Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 210, pl. 21, figs. 10, 10a, 1913.

Ptychaspis ? sp. undet. WALCOTT (part), idem, p. 186, pl. 17, fig. 1; pl. 21, fig. 14, 1913.

Upper Cambrian, Fengshan; (loc. C64) 3 miles southwest of Yenchuang, Shantung, China.

Holotype.—U.S.N.M. No. 58228; paratypes, Nos. 58229, 58113, 58127.

Quadraticephalus chosensis (Kobayashi)

Changia chosensis KOBAYASHI, Journ. Fac. Sci. Imp. Univ. Tokyo, sect. 2, vol. 4, pt. 2, p. 319, pl. 5, figs. 1, 2, 1935.

Upper Cambrian, Katsetsu (*Asioptychaspis* zone); Doten, south Chosen.

Holotype and paratypes.—Geol. Inst. Univ. Tokyo.

Quadraticephalus fengshanensis (Sun)

Ptychaspis ? fengshanensis SUN, Geol. Surv. China, Pal. Sinica, ser. B, vol. 7, fasc. 2, p. 31, pl. 4, fig. 13, 1935.

Upper Cambrian, Fengshan; Yehli, Kaiping basin, Hopei, China.

Holotype.—Nat. Peiping Univ. No. S1215.

SAUKIA Walcott, 1914

Saukia speciosa (Walcott)

Ptychasphis speciosus WALCOTT, 32d Rep. New York State Mus. Nat. Hist., p. 131, 1879; LESLEY, Geol. Surv. Pennsylvania Rep. P 4, p. 830, 1889; Walcott (part), Smithsonian Misc. Coll., vol. 57, No. 9, p. 272, pl. 43, figs. 16, 16a, 17, 19, 1912.

Upper Cambrian, Potsdam (Hoyt member); (loc. 76) 4 miles west of Saratoga Springs, New York.

Lectotype.—U.S.N.M. No. 58563; paratype, No. 58564.

Saukia eboracensis, new species

Lonchocephalus calciferus WALCOTT (part), Smithsonian Misc. Coll., vol. 57, No. 9, p. 270, pl. 43, fig. 9, 1912.

Dicellocephalus hartti WALCOTT (part), idem, p. 273, pl. 44, figs. 7, 7a, 1912.

Dikelocephalus hartti WALCOTT (part), ibid., No. 13, p. 368, pl. 63, figs. 7, 7a, 1914.

A libragene and a pygidium, as indicated in the bibliography, apparently belong together. Several small unillustrated cranidia also are candidates for the species. As the matter now stands the pygidium may be chosen as the type, and final assignment of cranidium awaits proper study of the fauna.

Axis prominent, extending about two-thirds the pygidial length, and connected with the rear edge by a sharp postaxial ridge. Axial furrows well developed. Pleural platforms small, sharply convex. Both the pleural grooves and furrows are clearly defined and run nearly to the margin, Pygidium as a whole very convex.

The libragene is characterized by a very long genal spine. Its ocular platform is covered by anastomosing lines that form a rather definite network. Toward the brim these lines become irregular striations. Eyes rather large.

Upper Cambrian, Potsdam (Hoyt member) ; 1 mile west of Saratoga Springs, New York.

Holotype.—U.S.N.M. No. 58577; paratype, No. 58556.

SEMNOCEPHALUS, new genus

Several species of trilobites with surface granulation were long ago described from the Yellowstone Park. They are characterized by their plump appearance. Similar species are now also in hand from the Canadian Rockies, and representatives of the genus may be expected elsewhere in the older Upper Cambrian beds.

Diagnosis.—Trilobites of average size. Cranidium alone known. The glabella is large, tapering to a rounded front. Glabellar furrows very shallow or wanting. Dorsal furrow clearly defined, and occipital furrow wide and rather deep. Fixigenes average a little more than half the glabellar width, and are slightly convex. Eyes small, situated about the midpoint of the cranidium. Faint eye lines traceable. Brim width slightly more than a third the glabellar length. It consists of a thickened elevated rim and a narrower preglabellar area. Suture intramarginal for some distance.

Owing to the down-turned anterior angles the front of the head is convex, but while the glabella and fixigenes are both convex across the eyes, the total relief thus obtained is not great. Longitudinally there is more convexity, attained by a gentle curvature of most of the glabella, but which increases rapidly in the anterior fourth and is further accentuated by the downward slope of the brim. Surface granulose.

Genotype.—*Solenopleura* (?) *weedi* Walcott (part).

Name.—σεμνος = portly; κεφαλη = head.

Semnocephalus weedi (Walcott)

Solenopleura ? weedi WALCOTT (part), U. S. Geol. Surv. Monogr. 32, pt. 2, p. 464, pl. 65, fig. 9, 1899.

Upper Cambrian, Pilgrim; Crowfoot Ridge, Gallatin Range, Yellowstone National Park, Montana.

Holotype.—U.S.N.M. No. 35236.

Semnocephalus minor, new species

Solenopleura ? weedi WALCOTT (part), U. S. Geol. Surv. Monogr. 32, pt. 2, p. 464, pl. 65, fig. 9a, 1899.

This name is applied to the smaller of the specimens figured by Walcott. It has smaller and fewer granules, and has a shorter glabella, more rounded in frontal outline.

Upper Cambrian, Pilgrim; Crowfoot Ridge, Yellowstone National Park, Montana.

Holotype.—U.S.N.M. No. 102322.

SHIRAKIELLA Kobayashi, 1935

Shirakiella carme (Walcott)

Anomocarella carme WALCOTT, Proc. U. S. Nat. Mus., vol. 29, p. 56, 1905.

Coosia carme WALCOTT, Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 211, pl. 21, fig. 7, 1913.

Upper Cambrian, Fengshan; (loc. C38) (*Asioptychaspis* zone) Chaumitien, Shantung, China.

Holotype.—U.S.N.M. No. 58226.

SOLENOPARIA Kobayashi, 1935

Solenoparia intermedia (Walcott)

Ptychoparia (*Liostracus*) *intermedia* WALCOTT, Proc. U. S. Nat. Mus., vol. 30, p. 592, 1906.

Solenopleura intermedia WALCOTT, Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 169, pl. 17, figs. 16, 16a, 1913.

Shumardia sp. undet. WALCOTT, idem, pl. 7, fig. 9, 1913.

Middle Cambrian, Changhia; (loc. C51) Chaumitien, Shantung, China.

Cotypes.—U.S.N.M. Nos. 58072, 58073, 57843.

Solenoparia pauperata (Walcott)

Solenopleura pauperata Walcott, Proc. U. S. Nat. Mus., vol. 30, p. 593, 1906; Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 169, pl. 17, fig. 18, 1913.

Middle Cambrian, Changhia; (loc. C71) 4 miles southwest of Tungyü, Shansi, China.

Holotype.—U.S.N.M. No. 58074.

Solenoparia tolus (Walcott)

Ptychoparia tolus Walcott, Proc. U. S. Nat. Mus., vol. 29, p. 82, 1905; Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 134, pl. 12, fig. 13, 1913.

Middle Cambrian, Changhia; (loc. C52) 3 miles northeast of Sin-tai-hien, Shantung, China.

Holotype.—U.S.N.M. No. 57956.

SOLENOPLEURELLA Poulsen, 1927

Solenopleurella resseri (Miller)

Bolaspis ? resseri Miller, Journ. Pal., vol. 10, No. 1, p. 27, pl. 8, fig. 39, 1936.

Middle Cambrian, Wolsey; south fork of Teton Creek, Teton Mountains, Wyoming.

Cotypes.—Columbia Univ. No. 12608.

STEPHENOCARE Monke, 1903

Stephenocare chaoi, new species

Stephenocare richthofeni Sun, Geol. Surv. China, Pal. Sinica, ser. B, vol. 1, fasc. 4, p. 32, pl. 2, figs. 5a-c, 1924.

This species, according to the drawings published by Sun, differs from *S. richthofeni* in several respects. The marginal spines on the rim appear to be shorter and differently spaced, and the rim itself, as drawn, appears thicker. Granules are more abundant, the rear pair of glabellar furrows more recurved, and the glabella less tapered. Spines are wanting along the rear edge, but they may simply have been overlooked in making the drawing.

Although the pygidium is incomplete, so that the length of the spines cannot be determined, it appears that the pleura are rather heavy. This species is considerably larger than *S. richthofeni.*

Middle Cambrian, Kushan; Lincheng, southern Chihli, China.

Cotypes.—Geol. Surv. China No. 522.

TAITZUIA Resser and Endo, 1935

Taitzuia RESSER and ENDO, *in* Kobayashi, Journ. Fac. Sci. Imp. Univ. Tokyo, sect. 2, vol. 4, pt. 2, p. 90, 1935; Manchurian Sci. Mus. Bull. 1, pt. 2, p. 292, 1937.

Menocephalites KOBAYASHI, Journ. Fac. Sci. Imp. Univ. Tokyo, sect. 2, vol. 4, pt. 2, pp. 259, 267, 268, 1935.

When *Menocephalites* was established simply to avoid the erroneous use of *Menocephalus,* it was not observed that the species involved fall naturally into *Taitzuia. Menocephalus* Owen was founded on a trilobite fragment from Wisconsin, believed to be the anterior glabellar lobe of a *Ptychaspis* species. Walcott used *Menocephalus* in Asia only because the species have a coarsely granulose surface. Such usage is, of course, untenable, for *Menocephalus* is a nomen nudum, but without giving due consideration to the characteristics of the Chinese species, *Menocephalites* was proposed in an offhand manner.

Species referred to *Menocephalites* now become *Taitzuia.*

Taitzuia abderus (Walcott)
T. acanthus (Walcott)
T. acerius (Walcott)
T. acidalia (Walcott)
T. acis (Walcott)
T. admeta (Walcott)
T. agave (Walcott)

Taitzuia adrastia (Walcott)

Menocephalus adrastia WALCOTT, Proc. U. S. Nat. Mus., vol. 29, p. 61, 1905.

Levisia adrastia WALCOTT, Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 177, pl. 16, figs. 5, 5a, 1913.

Middle Cambrian, Changhia; (loc. C30) Changhia, Shantung, China.

Holotype.—U.S.N.M. No. 58084; paratype, No. 58085.

TELLERINA Ulrich and Resser

Tellerina winchelli, new species

Pleurotomaria ? advena WINCHELL, Amer. Journ. Sci., vol. 27, p. 228, 1864.

Ptychaspis barabuensis WINCHELL (part), idem, p. 230, 1864.

The specimen that Winchell described as a gastropod is the rear portion of a trilobite glabella. Comparison of casts of Winchell's specimen with the trilobites from this locality seems to indicate that it represents a species of *Tellerina.* Also a libragene referred by Winchell to *Ptychaspis barabuensis* belongs to *Tellerina* and is accordingly referred to this species. In addition, a good cranidium is contained in the Winchell types, but to what species he referred it is not known at this writing. A good pygidium is contained in the National Museum collections.

As now constituted this species is typical of the genus in its simple brim construction, the libragenes with large ocular platforms, and the pygidium with a stout axis. It is further characterized by the anterior subdivision of the pleura expanding beyond the pleural platform to crowd out the posterior subdivision.

The cranidium assigned to the species has a large quadrangular glabella with one complete set of glabellar furrows anterior to the occipital. Another pair is indicated by short shallow furrows near the dorsal furrow. The simple brim is about as wide as the occipital ring. The fixigenes are confined largely to the palpebral lobes. There is a slight divergence of the suture anterior to the eye. The libragene assigned to the species is large throughout. The ocular platform in front is about as wide as the eye is long. A wide, heavy rim extends to the long, heavy genal spine.

A typical *Tellerina* pygidium occurs at the same locality as the cranidia and libragenes. It is characterized by a long, stout axis in which five rings are clearly demarcated. The axis is a little over half the length of the tail, and has a sharp postaxial ridge that extends nearly to the rear margin. The pleural platforms are small triangular affairs that do not reach the rear of the axis. The wide, slightly concave border is nearly smooth except that the anterior subdivision of the pleura, as it widens, remains visible nearly to the lateral margins. On the other hand, the rear pleural subdivision pinches out at the foot of the rather steep slope from the pleural platforms.

Upper Cambrian, Franconia (Devils Lake) ; (loc. 81b) near Devils Lake, Wisconsin.

Holotype.—U.S.N.M. No. 102323; paratypes, Univ. Michigan Nos. 2184, 21211; casts, U.S.N.M. No. 108131.

Tellerina scotlandensis, new species

Saukia stosei WALCOTT (part), Smithsonian Misc. Coll., vol. 57, No. 13, p. 384, pl. 70, figs. 12, 12a, 1914.

A pygidium referred by Walcott to *Saukia stosei* represents the genus *Tellerina.* It is characterized by the usual flaring border. The axis is well defined and extends about two-thirds the pygidial length, terminating in a pronounced postaxial ridge, which runs across more than half the border. Pleural grooves and furrows are present in average degree of development. The pygidium as a whole is rather narrow and consequently oblong in outline.

Upper Cambrian, Conococheague; (loc. 59n) quarry northwest of Scotland, Franklin County, Pennsylvania.

Holotype.—U.S.N.M. No. 59680.

TRIARTHROPSIS Ulrich, 1930

Triarthropsis blairi (Weller)

Ptychoparia blairi WELLER, Geol. Surv. New Jersey Pal., vol. 3, p. 116, pl. 1, figs. 10-13, 1903.

Ptychoparia newtonensis WELLER, idem, p. 117, pl. 3, fig. 10, 1903.

Acheilus ? blairi RAYMOND, Proc. Boston Soc. Nat. Hist., vol. 37, No. 4, p. 424, 1924.

Upper Cambrian, Kittatinny; Blairstown, and (loc. 11c) quarry near Newton, New Jersey.

Holotype.—Geol. Surv. New Jersey No. 5945; cast, U.S.N.M. No. 58929; plesiotype, Geol. Surv. New Jersey.

YABEIA Resser and Endo, 1931

Yabeia vicina (Walcott)

Agraulos vicina WALCOTT, Proc. U. S. Nat. Mus., vol. 30, p. 579, 1906; Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 160, pl. 15, fig. 8, 1913.

Megagraulos vicina KOBAYASHI, Journ. Fac. Sci. Imp. Univ. Tokyo, sect. 2, vol. 4, pt. 2, p. 207, 1935.

Middle Cambrian, Changhia; (loc. C70) 4 miles southwest of Tungyü, Shansi, China.

Holotype.—U.S.N.M. No. 58039.

Yabeia abrota Walcott

Agraulos abrota WALCOTT, Proc. U. S. Nat. Mus., vol. 29, p. 43, 1905; Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 156, pl. 15, fig. 3, 1913.

Metagraulos abrota KOBAYASHI, Journ. Fac. Sci. Imp. Univ. Tokyo, sect. 2, vol. 4, pt. 2, p. 207, 1935.

Middle Cambrian, Changhia; (loc. C23) 1 mile southeast of Changhia, Shantung, China.

Holotype.—U.S.N.M. No. 58034.

Yabeia dryas (Walcott)

Agraulos dryas WALCOTT, Proc. U. S. Nat. Mus., vol. 29, p. 46, 1905; Research in China, vol. 3, Carnegie Inst. Washington Publ. 54, p. 157, pl. 14, figs. 20, 20a, 1913.

Metagraulos dryas KOBAYASHI, Journ. Fac. Sci. Imp. Univ. Tokyo, sect. 2, vol. 4, pt. 2, p. 207, 1935.

Middle Cambrian, Changhia; (loc. C29) 1 mile west of Changhia, Shantung, China.

Holotype.—U.S.N.M. No. 58030.

Yabeia nana (Dames)

Anomocare nanum DAMES, Richthofen's China, vol. 4, p. 17, pl. 2, fig. 14, Berlin, 1883.

Metagraulos nanum KOBAYASHI, Journ. Geol. Soc. Japan, vol. 44, No. 524, p. 431, pl. 17, fig. 8, 1937.

Middle Cambrian, Taitzu; Taling, south of Hsiaoshih, Manchoukuo.

Holotype.—Natur. Mus. Berlin.

ZACANTHOIDES Walcott, 1888

Zacanthoides romingeri, new name

Embolimus spinosa ROMINGER, Proc. Acad. Nat. Sci. Philadelphia, p. 15, pl. 1, fig. 3, 1887.

Zacanthoides spinosus WALCOTT, Canadian Alpine Journ. vol. 1, pt. 2, pl. 4, fig. 1, 1908; GRABAU and SHIMER, North Amer. Index Foss., vol. 2, p. 273, fig. 1571, 1910.

In 1884 Walcott applied the name *spinosus* to the holotype of *Zacanthoides* from the Eureka district, Nevada. In 1887 Rominger described the Mount Stephen species as *Embolimus spinosa,* evidently without any thought of Walcott's species. When Walcott illustrated the Mount Stephen fossils in 1908, he changed the name of this species to *Z. spinosus,* but failed to notice that it is not conspecific with that at Eureka. Compared with *Z. spinosus* this species differs most conspicuously in its shorter cranidium and glabella.

Z. romingeri is characterized by a nearly rectangular glabella, which expands slightly forward. Four pairs of furrows are well developed, the rear pair slanting back almost to the transverse occipital furrow. The second pair also slants backward, but to a less degree, while the anterior pairs are directed slightly forward. The brim consists of a slightly thickened upturned rim, and the anterior furrow continues across the anterior angles. Eyes large, strongly bowed, the curvature increasing toward the rear. Heavy eye lines cross the narrow fixigenes. Fixigenes confined to large palpebral lobes, triangular anterior angles, and narrow strips at the front end of the eyes. Occipital ring expands greatly into a short but sharp-pointed spine. A node is present near each end of the ring.

Thorax has nine segments. Pleura deeply furrowed, extending into long slender spines, which have increasingly sharp angles at the fulcrum from front to back. Each axial ring carries a short spine.

Pygidium characteristic of the genus with a large, stout, highly convex axis, which extends nearly the full length of the pygidium and terminates with a short postaxial ridge. Five pairs of spines decrease in size from a very long, slender first pair to a minute fifth pair.

Middle Cambrian, Eldon; (loc. 14s) Mount Stephen, above Field, British Columbia.

Holotype.—Univ. Michigan No. 4871; plesiotypes, U.S.N.M. No. 102324.

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SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 101, NUMBER 16

THE SNOW AND ICE ALGAE OF ALASKA

(WITH 6 PLATES)

BY
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Department of General Botany of
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(PUBLICATION 3683)

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THE SNOW AND ICE ALGAE OF ALASKA[1]

By ERZSÉBET KOL[2]

Department of General Botany of Franz Joseph University, Kolozsvár, Hungary

(With 6 Plates)

INTRODUCTION

Up to the present time little has been known of the microorganisms of the snowfields and icefields of Alaska. The microorganism causing "red snow" was mentioned by Saunders (1901, p. 409) under the name *Sphaerella lacustris* (Girod.) Wittr. as being present in Yukatat Bay and on Muir Glacier, on the snow above Orca, Prince William Sound, and, according to Setchell (1903, p. 203) it is reported under the name *S. nivalis* (Bauer) Sommerf. from Unalaska. This red snow is probably due to organisms of the *Chlamydomonas nivalis* group which cause the red coloring of snowfields the world over.

In the summer of 1936 I was able to study the organisms of the snowfields and icefields in Alaska. As there had been no earlier study in this area, I endeavored to search the snowfields in widely separated mountain ranges for cryoplankton. I carried out researches in the mountain ranges on the coast and also in the interior of the Alaskan peninsula, I collected snow and ice algae on the Alaskan Range, and on the Wrangell Mountains in the interior, on the Chugatch Mountains and on the Coast Range, as shown by the accompanying map (fig. 1). It is most desirable that, at some future time, this research should be continued in the northern part of the Territory, because conditions in Alaska are exceptionally favorable for the growth of organisms in snow and ice, and there is much valuable information to be obtained there by biologists.

The developmental cycle of the snow-inhabiting organisms is not exactly known, nor do we even know what role these organisms play

[1] Owing to the impossibility of communicating with the author because of war conditions, the final revision of the manuscript and the reading of the proof was very kindly done by Prof. William Randolph Taylor, of the Department of Botany, University of Michigan.—Editor.

[2] Holder of the Crusade International Fellowship of the American Association of University Women for the academic year 1935-36. The Alaskan work was conducted under a grant from the Smithsonian Institution, for which the writer is deeply grateful.

in the biological cycle of areas covered by snow or ice, nor yet what higher organisms they may serve as exclusive food. Heretofore it has been necessary to conduct in the field such investigations as were possible, because the organisms could not be cultivated in warm lowland laboratories, and research in the field in areas of permanent snow and ice is handicapped by the difficulties of transporting necessary apparatus. However, a laboratory established at an altitude of 11,382 feet in the Jungfrau Pass, Switzerland, will be very helpful to study of the cryovegetation, and if other laboratories in like situations of extreme environmental conditions can be provided such studies will be made much more profitable.

In order to avoid repetition I append a list of the localities at which cryobiological samples were collected, and shall refer to them by number alone in the systematic portion of this paper.

A. Catalog of Alaskan Collections, 1936, by E. Kol

ALASKAN RANGE

Mount McKinley National Park: Head of the Savage River at an Altitude of About 4,500 Feet, July 21

1. The upper snowfield, snow surface with pH = 6.
2. Another part of the same snowfield, pH = 5.8.
3. A lower snowfield beside a brook, pH = 6.5.
4. Snowfield in the first little valley, surface pH = 6.5, but pH at a depth of 20 cm. = 5.5.

Teklanika Glacier, Teklanika Valley at an Altitude of About 4,500 Feet. July 24

14. From the ice surface, pH = 7.5.
15. From another part of the glacier.
16. From yet another part of the glacier, pH = 5.5.

WRANGELL MOUNTAINS

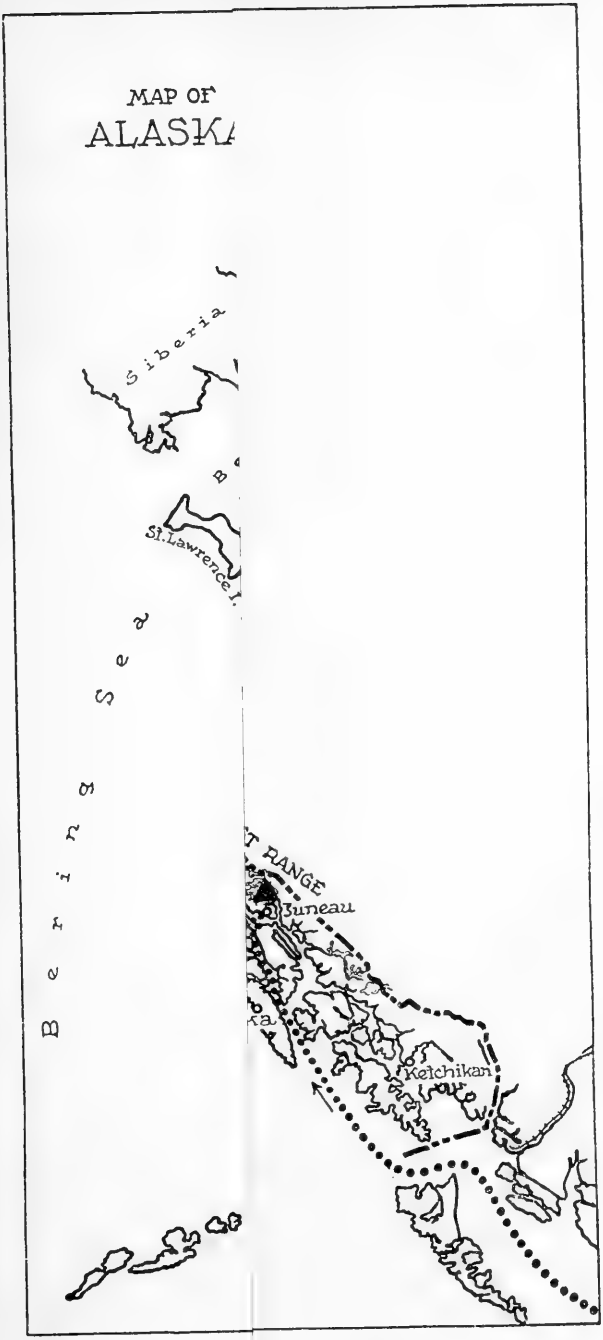
Kennicott Glacier. July 31

19. From the surface of the glacier, pH = 5.5.
20. From another part of the glacier.
21. From the pure ice.
22–24. From yet other parts of the glacier.

CHUGATCH MOUNTAINS

Worthington Glacier at About 2,070 Feet Altitude. August 2

28. From the ice of the glacier, pH = 5.0.
29. From another part of the glacier.
30. Dust from the same glacier.
31. Mud from the glacier.



MAP OF
ALASKA
Siberia
St.Lawrence I.
Bering Sea
RANGE
Juneau
Ketchikan

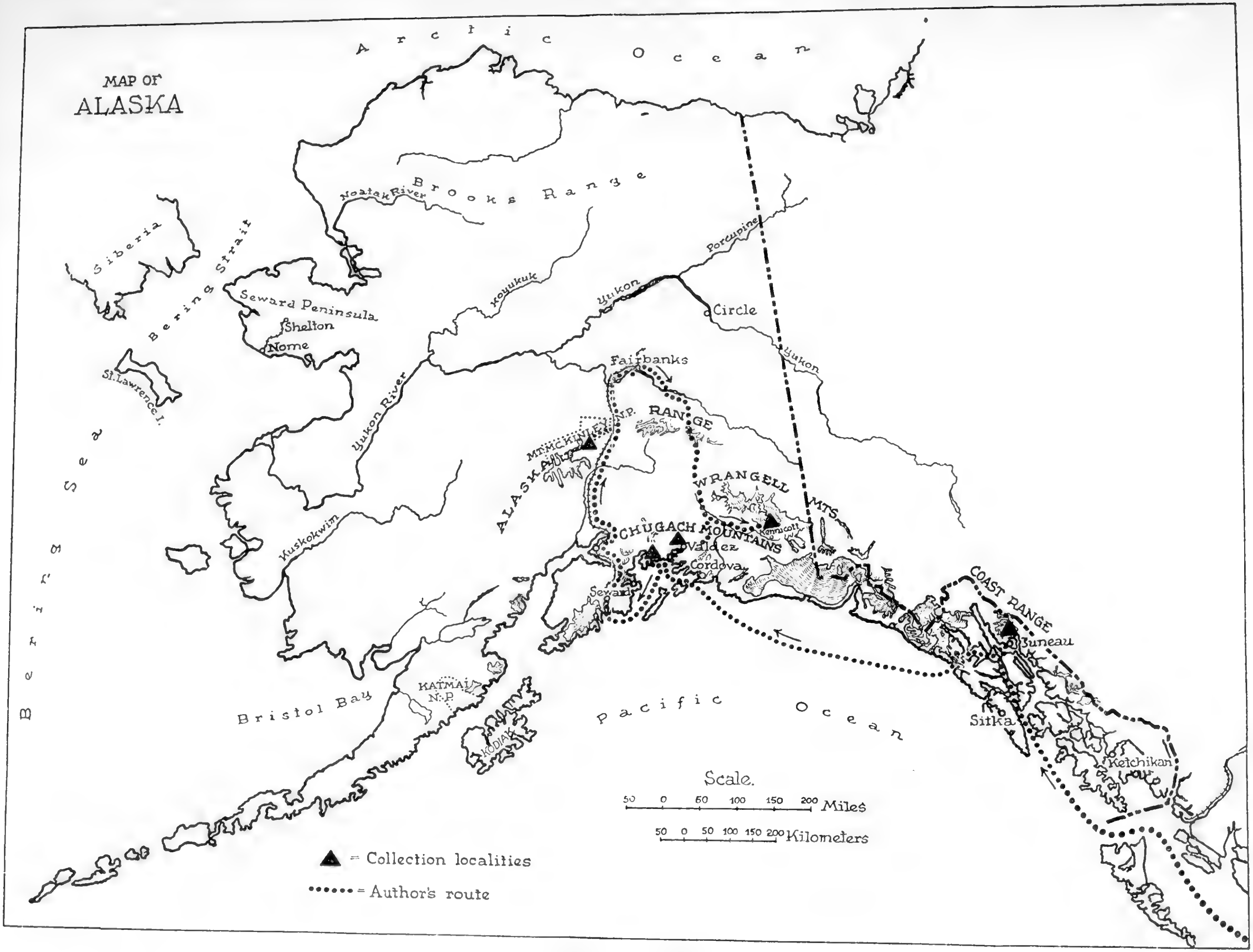


FIG. 1.—Map of Alaska showing author's route.

Thompson Pass, at an Altitude of 2,722 Feet. August 6

35. Red snow, pH = 5.0.
36. Red snow from another little snowfield.
37. From yet another snowfield.
43. Snow from the Pass.
44. From a small snowfield at the side of the Pass.
45. From a neighboring snowfield.
46. From a lower snowfield.
47. From a small neighboring snowfield.
48. From a red snowfield in the Pass, pH = 5.0.

Columbia Glacier. August 5

38. From the ice, pH = 5.0.
39. From another part of the glacier.

Valdez Glacier. August 6

52. From the ice, pH = 5.0.

COAST RANGE

Mendenhall Glacier. August 12

53. From the ice, pH = 5.0.
54. From another part of the glacier.

Roberts Peak, Altitude 3,810 Feet. August 15

60. From a little snowfield on the ascent to the peak above Juneau, pH = 5.5.
61. From a neighboring snowfield.

Gastineau Peak, Altitude 3,666 Feet. August 15

62. From a lower snowfield, pH = 5.0.
63. Snow from the side of the peak.
64. Snow fleas from another snowfield, altitude 2,500 feet.
65. Same, preserved in methyl alcohol.
66. Same, preserved in formalin.
67. From another snowfield.

B. Catalog of Alaskan Collections, 1936, by H. J. Liek

MOUNT McKINLEY NATIONAL PARK

Muldrow Glacier. July 22

12. From the ice of the glacier.

Toklat Glacier. September 4

70, 71. From the ice face.
72. From the ice of the glacier.
73–75. Snow from the glacier.

East Fork Glacier. August 22

76. From ice of the glacier.
77. From the surface of the glacier.

In the course of these studies part of the research was carried out in Alaska on living material, part was carried out on living material which I brought away with me, and part was based on material preserved in formalin. For 4 years I maintained my cultures of living material, but they were ultimately lost in October 1940 on the removal of the Franz Joseph University to Kolozsvár, so that now only the preserved material remains. This, in small glass tubes in 4 to 5 percent formalin, is in duplicate, one set being in the possession of the Smithsonian Institution in Washington, the other in the department of general botany of the Franz Joseph University in Kolozsvár, Hungary.

I am deeply grateful to the Smithsonian Institution and its Secretary, Dr. C. G. Abbot, for enabling me to carry out my investigations. I am also indebted to Prof. I. Györffy, and to all who have helped with the research. For the collections from glaciers in Mount McKinley National Park, I must thank the Superintendent, Harry J. Liek.

CRYOENVIRONMENTS

The development of phytoplankton of fresh water is influenced by the chemical and physical character of the water, and in the same way the comparable factors in what may be termed the cryoenvironment of snow and ice act as the controlling factors in the development of the vegetation there, which we may call the cryovegetation. As we understand it today, the snow- and ice-inhabiting organisms, the cryobionts, live very close to the surface and so the changes that take place on the surface of the snow and ice fields are those which exert the chief influence on these organisms.

The minute particles falling from decomposing and shattered rock, and the wind-borne dust, dissolve slowly in the moisture more or less continuously present on the surface, which is always rich enough in oxygen. This water then serves as the mineral source for the microorganisms. It thus becomes clear that the vegetation is influenced by the chemical nature of the rocks that form the surrounding mountain slopes. Consequently, snowfields and glaciers lying among mountains composed of acid rocks will have a different vegetation from those which are surrounded by limestone. On the basis of my European experience I have divided the cryoenvironments into silicotroph and calcitroph types (Kol 1933, p. 283).

Changes in the pH of the surface snow and ice influence the composition of the vegetation on its surface, just as does the salt content. Therefore an attempt was made to obtain data to show the extent of the influence of this factor, together with the other observations, during the study of the cryoenvironments of Alaska.

TABLE 1.—*Result of measurements of pH*

(The values in this table are mean results of repeated measurements, which were made with a Hellige comparator.)

	Surface of snow	Surface of ice	At depth of 1 foot	Water	Date *1936*
Alaskan Range:					
Mount McKinley National Park					
Head of the Savage River,					
snowfield: a	5.8	...	...	...	July 21
b	6.0	...	...	...	
c	6.5	...	...	...	
d	6.0	...	...	...	
e	6.5	...	5.5	...	
f	5.8	...	...	...	
g	6.0	...	5.5	...	
Melted water of the snowfield	...	...	...	6.5	
Teklanika Glacier	5.5	7.0	...	...	July 24
Water flowing on the surface of the ice	...	...	...	7.0	
Wrangell Mountains:					
Kennicott Glacier: a	5.5	4.5	...	...	July 31
b	...	5.0	...	...	
Stream at side of the glacier	...	...	...	8.0	
Melted water of the glacier	...	...	...	6.0	
Chugatch Mountains:					
Worthington Glacier	...	5.0	...	...	Aug. 2
Melted water of the glacier	...	...	...	6.0	
Stream at side of glacier	...	...	...	6.0	
Columbia Glacier: a	...	5.0	...	...	Aug. 5
b	...	5.0	...	...	
Melted water of the glacier	...	...	...	5.5	
Glacier stream	...	...	...	7.0	
Thompson Pass, red snow-field: a	5.0	...	...	...	Aug. 6
b	5.0	...	5.0	...	
c	5.2	...	...	...	
Melted water of the snowfield	...	...	...	6.0	
Valdez Glacier	...	5.0	...	...	
Coast Range:					
Mendenhall Glacier: a	...	5.0	...	...	Aug. 12
b	...	5.0	...	...	
Melted water of glacier	...	...	...	5.5	
Glacier stream	...	...	...	7.5	
Roberts Peak, snowfield: a	4.5	...	...	...	Aug. 15
b	5.0	...	...	...	
Gastineau Peak, snowfield: a	5.0	...	...	...	
b	5.0	...	...	...	
Melted water of snowfields	...	...	...	5.2	

It can be clearly seen from table 1 that the plants of the Alaska snowfields are mostly of the silicotroph type, which appears as a vegetation of red or pink snow. The pH of the field surface may differ from that found deeper in the mass, where it becomes more acid. When the reaction at the surface is pH 6.5, at a depth of 1 foot it may be 5.5, and to this depth the effect of the solution of mineral particles progressively decreases. Calcitroph snowfields were not met in Alaska, and their characteristic vegetation of green snow seems not to have been reported from America. There were some fields with a pH of 6.5 or 6.0, such as those at the head of the Savage River, but their microvegetation at the time of my visit was very poor. These fields showed only a few specimens of *Raphidonema* and of *Scotiella nivalis;* because of their location and the many rock fragments on their surfaces (pl. 2, fig. 4) they were unsuitable for development of a mass vegetation. The icefields throughout showed a pH of 5.0, except that of the Teklanika Glacier, which gave pH 7.0.

It is also possible to divide the cryoenvironments according to their physical character, and I recognize the following: 1, snow; 2, firn[3]; 3, snow over glacier ice; 4, pure ice. These physical types show differences in cryovegetation.

CLASSIFICATION OF THE CRYOBIONTS

A classification based on the preferred environments is possible; in some cases the choice is exclusive, but in others there is more or less adaptability to various conditions.

1. On the ice, and never found on snow, constituting characteristic ice algae which may be termed glacialis-cryobionts, are for example: *Ancyclonema* sp., and *Mesotaenium Berggrenii.*

2. On the snow and firn, but never on ice, constituting the snow algae or nivalis-cryobionts, are for example: *Raphidonema* spp., *Chlamydomonas nivalis, Scotiella nivalis, Chionaster bicornis.*

3. There may be recognized a group adapted both to snow and to ice, and these may be termed mixo-cryobionts, with *Cylindrocystis Brebissonii, Trochiscia nivalis,* and *T. antarctica* as examples.

4. Microorganisms appear on snow and ice which do not have this as their proper home, being transferred there from their normal location on neighboring damp cliffs. These are not real cryobionts, but may be termed cryoxen. Examples would be: *Gloeocapsa Ralfsiana, G. sanguinea, Stichococcus bacillaris, Phormidium antarcticum.*

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[3] The term "firn" is given to the snow above the glaciers, which is partly consolidated by alternate thawing and freezing but has not become glacier ice.

TABLE 2.—*The snow and ice microorganisms of Alaska*

(The numbers in this table refer to the localities where samples were taken. See pp. 2-3.)

Microorganisms	Alaskan Range Mt. McKinley National Park					Wrangell Mts.	Chugatch Mountains				Coast Range							
	Head of the Savage River	Teklanika Glacier	Toklat Glacier	East Fork Glacier	Muldrow Glacier	Kennicott Glacier	Worthington Glacier	Thompson Pass	Valdez Glacier	Columbia Glacier	Mendenhall Glacier	Roberts Peak	Gastineau Peak	Microorganisms of snow	Microorganisms of ice	pH of the cryoenvironments	Occurrence of microorganisms	Type of microorganisms
ALGAE																		
CHLOROPHYCEAE																		
Protococcales																		
Chlamydomonas nivalis Wille	1, 3, 4	14–16	73, 74	77				35, 36, 43, 44, 47, 48				60	62, 63, 64	+		4.5–7.0	Very common	Nivalis
Chlamydomonas sanguinea Lagerh.		14						43					64	+		4.5–6.0	Rare	Nivalis
Smithsonimonas Abbotii Kol			73, 74	77				35, 36, 43, 46					62	+		5.0–5.2	Not rare	Nivalis
Scotiella nivalis (Shuttlew.) F. E. Fritsch	1		70–75	76, 77				35, 43, 46, 48	52		53	60	62	+		4.5–6.5	Very common	Nivalis
Scotiella antarctica F. E. Fritsch								43				60	63, 64	+		4.5–6.5	Rare	Nivalis
Scotiella polyptera F. E. Fritsch		14–16						43						+		5.0–5.2	Very rare	Cryoxen
Chlorosphaera antarctica F. E. Fritsch						19				38, 39				+		4.5–7.0	Not rare	Glacialis
Mycacanthococcus cellaris f. *antarctica* Wille						21	29	35, 43					64	+		4.5–5.5	Not rare	Nivalis
Mycacanthococcus ovalis var. *juneauensis* Kol													63	+		5.0	Very rare	Nivalis
Trochiscia antarctica F. E. Fritsch										38, 39					+	5.0	Rare	Mixo-cryobiont
Trochiscia nivalis Lagerh.										38, 38					+	5.0	Rare	Mixo-cryobiont
Trochiscia cryophila f. *longispina* Kol										38, 39					+	5.0	Rare	Glacialis
Trochiscia cryophila f. *brevispina* Kol									52	38, 39					+	5.0	Very rare	Glacialis
Tetraedron valdezii Kol								46, 47					63	+		5.0–5.2	Very rare	Nivalis
Pleurococcus vulgaris β *cohaerens* Wittr.								35						+		5.0	Very rare	Nivalis
Chaetophorales																		
Raphidonema brevirostre Scherffel								35						+		5.0–5.2	Very rare	Nivalis
Raphidonema nivale Lagerh.								35, 43, 47				60		+		4.5–5.2	Not rare	Nivalis
Stichococcus bacillaris Näg.								47						+		5.2	Rare	Cryoxen
Zygnematales																		
Ancyclonema Nordenskioldii Berggr.		14–16				19–23	28, 29		52	38, 39	53, 54				+	4.5–7.0	Very common	Glacialis
Mesotaenium Berggrenii var. *alaskana* Kol		14–16			12	19, 20	28, 29		52	38, 39	53				+	4.5–7.0	Very common	Glacialis
Cylindrocystis Brebissonii f. *cryophila* Kol		14–16			12	19, 20	28, 29		52	38, 39	53, 54			+		4.5–7.0	Common	Mixo-cryobiont
Closterium exile var. *unicrystallatum* Kol											54		62	+	+	5.0	Very rare	Mixo-cryobiont
CYANOPHYCEAE																		
Chroococcales																		
Gloeocapsa Ralfsiana (Harv.) Kütz								35, 43, 44, 47, 48		38, 39	54	60	62, 63	+	+	4.5–5.2	Common	Cryoxen
Gloeocapsa sanguinea (C. Agardh.) Kütz								47		38			62	+	+	4.5–5.2	Rare	Cryoxen
Dactylococcopsis alaskana Kol												60		+		4.5	Rare	Nivalis
Hormogonales																		
Oscillatoria tenuis var. *teklanikana* Kol		16				20									+	5.0–5.2	Very rare	Glacialis
Phormidium antarcticum West		14, 16				23				38, 39					+	5.0–7.0	Not rare	Cryoxen
Phormidium glaciale West		15													+	5.5	Rare	Cryoxen
Lyngbya Martensiana var. *mendenhalliana* Kol											54				+	5.5	Very rare	Glacialis
Lyngbya Lagerheimii var. *Liekii* Kol		15													+	5.5	Very rare	Glacialis
FUNGI																		
Chionaster bicornis Kol		16										60		+		4.5–5.5	Common	Nivalis
Rhizophidium sphaerocarpum subsp. *cryophilum* Bérczi									52	38, 39					+	5.0	Common	Glacialis

THE CRYOBIOTA OF ALASKA

The variation in the composition of the algal vegetation in the cryoenvironments of Alaska is shown in table 2. From the table it may clearly be seen that some organisms, as *Ancylonema Nordenskioldii* and *Mesotaenium Berggrenii* var. *alaskana,* are exclusively to be found on ice. The former was noted on the interior glaciers of Alaska, such as Teklanika, Worthington, and Kennicott, as well as on the ice of the coastal glaciers, Valdez, Columbia, and Mendenhall, though now only the Columbia actually reaches the sea. These glacial ice sheets are seldom, perhaps never, covered by snow, because the temperature of the sea coast here seldom becomes low enough even in the winter to permit the deposition of snow on the glacier surface only a few feet above sea level. This produces an environment ideal for ice organisms. Rarely does one find a nivalis- or mixo-cryobiont organism among them. Pure ice dominates the aspect of the region. Under favorable circumstances in such an area ice algae give a peculiar color to the surface of the icefield.

In contrast to this, mass vegetation is very rare on the inland glaciers, and their surfaces are often covered with snow. Especially at high elevations glaciers are often exposed to snowfalls, and then nivalis- and glacialis-cryobionts occupy the snow-covered or uncovered pure ice areas, while organisms derived from neighboring cliffs cause a mixed vegetation in some places.

The algal vegetation for each location is given below:

I. Snowfields

Alaskan Range, Mount McKinley National Park:

Head of the Savage River (samples 1-4)

	Occurrence
Chlamydomonas nivalis	Few
Scotiella nivalis	Few

The vegetation here is very scanty. The samples also contain hyphae and spores of fungi, phanerogam pollen, fragments of various plants, and very large quantities of cryoconite (gray dust found on the surface of the ice).

Thompson Pass (red snow, samples 35-37, 43, 48)

	Occurrence
Chlamydomonas nivalis	Very many
C. sanguinea	Many
Smithsonimonas Abbotii	Very many
Scotiella nivalis	Many
S. antarctica	Many
S. polyptera	Isolated
Mycacanthococcus cellaris f. *antarctica*	Few
Tetraedron valdezii	Very few
Pleurococcus vulgaris var. *cohaerens*	Few
Raphidonema brevirostre	Few
R. nivale	Few
Stichococcus bacillaris	Isolated
Gloeocapsa Ralfsiana	Few
G. sanguinea	Isolated

The vegetation, appearing as a red snow bloom, is very rich. In the samples were also frustules of diatoms, hyphae and spores of fungi, phanerogam pollen, and spores of cryptogams, fragments of various plants and large quantities of cryoconite.

Roberts Peak (samples 60, 61)

	Occurrence
Chlamydomonas nivalis	Many
Scotiella nivalis	Many
S. antarctica	Few
Raphidonema nivale	Few
Gloeocapsa Ralfsiana	Few
Dactylococcopsis alaskana	Few
Chionaster bicornis	Very few

The vegetation appears poor. The samples contain also frustules of diatoms, hyphae and spores of fungi, spores of cryptogams and phanerogam pollen, fragments of various plants, and large quantities of cryoconite.

Gastineau Peak (samples 62-67)

	Occurrence
Chlamydomonas nivalis	Many
C. sanguinea	Few
Smithsonimonas Abbotii	Few
Scotiella nivalis	Many
S. antarctica	Few
Mycacanthococcus cellaris f. *antarctica*	Isolated
M. ovalis var. *juneauensis*	Few
Closterium exile var. *unicrystallatum*	Very few
Gloeocapsa Ralfsiana	Few
G. sanguinea	Very few

The vegetation should not be considered as a poor one. There were associated very many nests of *Isotoma,* or snow fleas. In the samples also were frustules of diatoms, spores of fungi, phanerogam pollen, fragments of various plants, and cryoconite.

II. Glaciers

Teklanika Glacier (samples 14-16)

	Occurrence
Chlamydomonas nivalis	Many
C. sanguinea	Few
Chlorosphaera antarctica	Few
Ancyclonema Nordenskioldii	Few
Mesotaenium Berggrenii var. *alaskana*	Few
Cylindrocystis Brebissonii f. *cryophila*	Very few
Oscillatoria tenuis var. *teklanikana*	Few
Phormidium antarcticum	Few
P. glaciale	Few
Lyngbya Lagerheimii var. *Liekii*	Few
Chionaster bicornis	Few

The vegetation is not a rich one. The samples in addition contained the frustules of diatoms, spores of fungi, phanerogam pollen, fragments of various plants, and much cryoconite.

Toklat Glacier (samples 70-75)

	Occurrence
Chlamydomonas nivalis	Few
Smithsonimonas Abbotii	Few
Scotiella nivalis	Many

The vegetation is very poor. The samples contained spores of fungi, the leaves of mosses, fragments of higher plants, and cryoconite in very large quantities.

East Fork Glacier (samples 76, 77)

	Occurrence
Chlamydomonas nivalis	Few
Smithsonimonas Abbotii	Very few
Scotiella nivalis	Many

The vegetation is very poor. The samples also contained spores of fungi, fragments of various plants, and cryoconite in very large quantities.

Muldrow Glacier (sample 12)

	Occurrence
Mesotaenium Berggrenii var. *alaskana*	Few
Cylindrocystis Brebissonii f. *cryophila*	Very few

The vegetation is very poor. The samples also contain fragments of different plants and very large quantities of cryoconite.

Kennicott Glacier (samples 19-24)

	Occurrence
Chlorosphaera antarctica	Few
Mycacanthococcus cellaris f. *antarctica*	Very few
Ancyclonema Nordenskioldii	Many
Mesotaenium Berggrenii var. *alaskana*	Many
Cylindrocystis Brebissonii f. *cryophila*	Few
Oscillatoria tenuis var. *teklanikana*	Very few
Phormidium antarcticum	Few

The vegetation is rich. The samples also contained frustules of diatoms, spores of fungi, phanerogam pollen, fragments of various plants, and cryoconite.

Worthington Glacier (samples 28-31)

	Occurrence
Mycacanthococcus cellaris f. *antarctica*	Very few
Ancyclonema Nordenskioldii	Many
Mesotaenium Berggrenii var. *alaskana*	Many
Cylindrocystis Brebissonii f. *cryophila*	Few

The vegetation was a rich one. The samples also contained spores of fungi, phanerogam pollen, plant fragments, and much cryoconite.

Valdez Glacier (sample 52)

	Occurrence
Scotiella nivalis	Few
Trochiscia cryophila f. *brevispina*	Very few
Ancyclonema Nordenskioldii	Many
Mesotaenium Berggrenii var. *alaskana*	Many
Cylindrocystis Brebissonii f. *cryophila*	Few
Rhizophidium sphaerocarpum subsp. *cryophilum*	Isolated

The vegetation is a rich one. The samples also contained phanerogam pollen, plant fragments, and much cryoconite.

Columbia Glacier (ice bloom, samples 38, 39)

	Occurrence
Chlorosphaera antarctica	Many
Trochiscia antarctica	Very few
T. nivalis	Very few
T. cryophila f. *longispina*	Very few
T. cryophila f. *brevispina*	Very few
Ancyclonema Nordenskioldii	Very many
Mesotaenium Berggrenii var. *alaskana*	Very many
Cylindrocystis Brebissonii f. *cryophila*	Few
Gloeocapsa Ralfsiana	Few
G. sanguinea	Very few
Phormidium antarcticum	Few
Rhizophidium sphaerocarpum subsp. *cryophilum*	Few

The vegetation is a very rich one, forming an ice bloom. The samples also contained phanerogam pollen, plant fragments, and cryoconite.

Mendenhall Glacier (samples 53, 54)

	Occurrence
Scotiella nivalis	Few
Ancyclonema Nordenskioldii	Many
Mesotaenium Berggrenii var. *alaskana*	Many
Cylindrocystis Brebissonii f. *cryophila*	Few
Closterium exile var. *unicrystallatum*	Isolated
Gloeocapsa Ralfsiana	Few
Lyngbya Martensiana var. *mendenhalliana*	Few

The vegetation was a rich one. The samples also contained frustules of diatoms, fragments of various plants, and cryoconite.

On nearly every glacier one may find *Ancyclonema Nordenskioldii, Mesotaenium Berggrenii,* var. *alaskana,* and *Cylindrocystis Brebissonii* f. *cryophila,* while *Chlamydomonas nivalis* and *Scotiella nivalis* appear on nearly every snowfield. The presence of the different microorganisms depends on the environmental factors, and their optimal development upon the dominating factors in the cryoenvironment, but transportation of the spores by wind is necessary to the establishment of these plants (Pettersson 1940, p. 73).

Table 2 also shows that the cryobionts find the requisite pH for development between pH 4.5 and 7.0. The cryobionts of ice of the silicotroph snowfields require approximately pH 5.0. It is to be recognized from the above list that both in variety of species and in mass the vegetation of the snowfields of Thompson Pass and the ice vegetation of the Columbia Glacier were the richest in their respective categories The Alaskan specimens comprise 13 nivalis-cryobionts, 9 glacialis-cryobionts, 4 mixo-cryobionts, and 5 cryoxen.

RED SNOW

On August 5 there were snowfields lying on the inner side of Thompson Pass upon which, almost without exception, red snow was clearly to be seen from the highroad. The color was deepest where the snow spread over the rubble-covered incline along the road at the top of the Pass. As is generally the case with red snow, it appeared in spots scattered over the surface. The red color was centered about a point in the middle of the bright-colored snowfield in the Pass, with the coloration progressively paler farther from the center. Likewise the depth of penetration varied from about 2 feet in the central area to the marginal spots, where only the surface was colored. This distribution showed resemblance to the spread of an organism in culture from the point of inoculation. Probably the central point here also represented the original point of colonization, from which the organism spread. In most cases the spores of these microorganisms are scattered by wind (Pettersson, 1940, p. 1 ff.), and this easily explains how such a macroculture could appear on the surface of a snowfield. The shade of red on Thompson Pass resembled a sprinkling of red pepper, rather than the light raspberry red of other snowfields, and probably is due to the fact that *Chlamydomonas nivalis, C. sanguinea,* and *Gloeocapsa Ralfsiana* join in causing the color, together with *Smithsonimonas Abbotii* and three species of *Scotiella,* their orange-red and yellow color contributing to alter the shade. A similar society of algae forming red snow has not been found elsewhere. It can be said that from the point of view of quantity and of variety, the cryovegetation of Thompson Pass is the richest observed in Alaska. I found 14 kinds of algae on these fields, 10 nivalis-cryobionts and 4 cryoxens, with hardly any glacialis-cryobionts among them.

SNOW FLEAS

Another very interesting phenomenon of the Alaskan snowfields, not part of the vegetation, but nevertheless frequent in the cryo-environment, is the occurrence of colonies of snow fleas of the genus *Isotoma* (Collembola). On September 5 I noticed on a small snowfield at an altitude of 3,000 feet on the side of Gastineau Peak above Juneau a bluish-gray (steel-gray) spot on the dirty surface of the

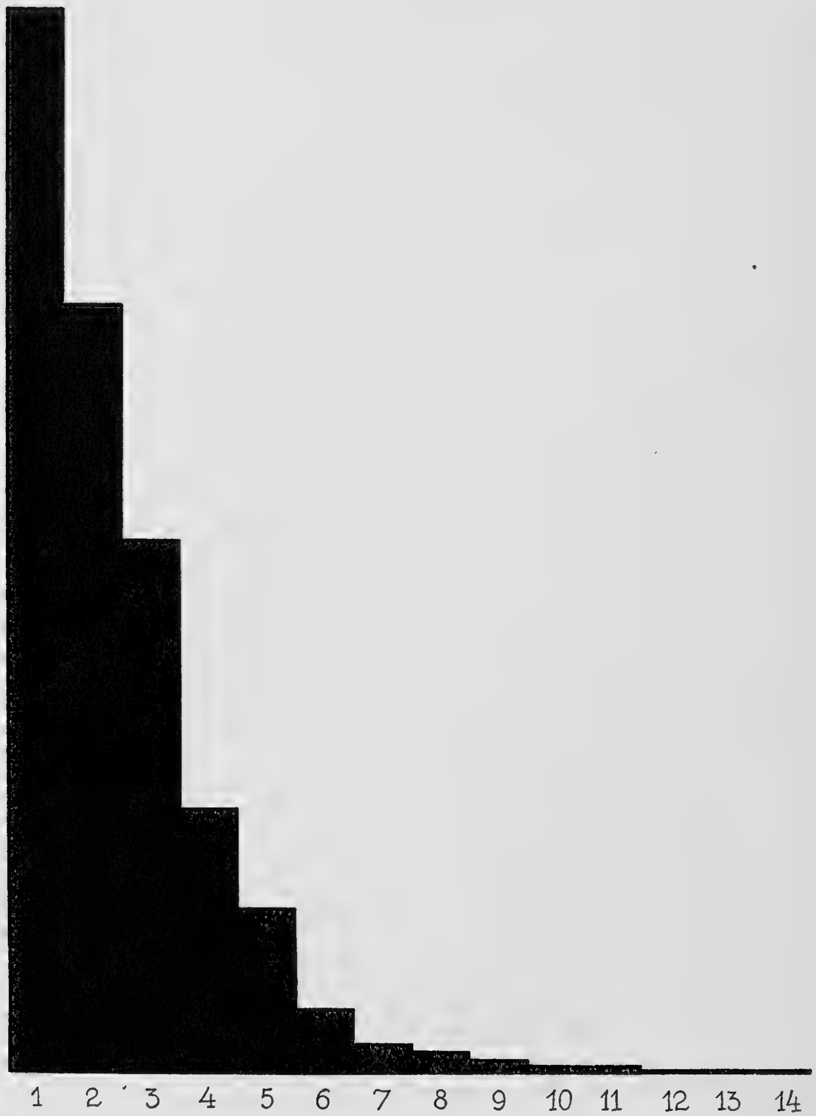

Fig. 2.—The quantitative relations of the microorganisms of the red snow on Thompson Pass. 1, *Chlamydomonas nivalis;* 2, *Smithsonomonas Abbotii;* 3, *Scotiella nivalis;* 4, *Chlamydomonas sanguinea;* 5, *Gloeocapsa Ralfsiana;* 6, *Scotiella antarctica;* 7, *Pleurococcus vulgaris β cohaerens;* 8, *Raphidonema nivale;* 9, *Mycacanthococcus;* 10, *Tetraedron valdezii;* 11, *Raphidonema brevirostre;* 12, *Gloeocapsa sanguinea;* 13, *Scotiella polyptera;* 14, *Stichococcus bacillaris.*

FIG. 3.—The quantitative relations of the microorganisms of the ice bloom of Columbia Glacier. 1, *Ancyclonema Nordenskioldii;* 2, *Mesotaenium Berggrenii* var. *alaskana;* 3, *Chlorosphaera antarctica;* 4, *Cylindrocystis Brebissonii* form *cryophila;* 5, *Gloeocapsa Ralfsiana;* 6, *Phormidium antarcticum;* 7, *Trochiscia antarctica;* 8, *Trochiscia cryophila* form *longispina* and form *brevispina;* 9, *Trochiscia nivalis;* 10, *Gloeocapsa sanguinea;* 11, *Rhizophidium sphaerocarpum* subsp. *cryophilym.*

snow which proved to be a nest of these. The thin covering of snow here was full of many thousands of lively *Isotoma.* According to the work of Wailes (1935, p. 1) snow fleas are frequent on the Canadian snowfields, and they are known in Europe as well.

ICE BLOOM

On August 5 I succeeded in reaching the Columbia Glacier by means of a little motorboat. This is one of the most active glaciers in Alaska and is also one of the greatest on the coast. It is located at about long. 174° W., lat. 61° N., in the vicinity of Valdez. Descending into Columbia Bay, it forms an ice wall 150 to 250 feet high, is about 25 miles long and 3 to 4 miles wide. I approached the glacier from the east side and collected cryoorganisms from the ice surface at about 1 mile from the ocean. The surface of the ice was not covered by snow at this place, as it usually is at higher altitudes where there are frequent snowfalls. By several measurements the ice was found to have a pH of 0.5. For many miles it showed an ice bloom, characterized by *Ancylonema Nordenskioldii* and *Mesotaenium Berggrenii* var. *alaskana.* The greatest mass of vegetation was on the Columbia Glacier. On the Mendenhall Glacier there was a much smaller quantity causing a pale bloom.

In these places *Ancylonema* forms long filaments in bunches 1 to 2 mm. in diameter on the ice surface. These are sometimes close together, sometimes a few centimeters apart. The ice bloom is rare in the interior of Alaska but more frequent on the coast glaciers. We can find little about this phenomenon in the literature, but this means, not that it is rare, but that few scientists have visited its habitats, chiefly in the Arctic regions. So far as I know only A. E. Nordenskiöld and S. Berggren have seen it, on the Greenland ice in July 1870 (Wittrock 1883, p. 65 ff). The color of the bloom on the Columbia Glacier ice was purple brown from a moderate distance (pl. 1, fig. 4). When observed closely, the bundles of algal filaments could be seen (pl. 1, figs. 3, 5), spread irregularly over the ice surface, clearly visible to the unaided eye. The chief mass was due to *Ancylonema,* but *Mesotaenium* was also abundant. The filaments of *Ancylonema* (pl. 1, figs. 3, 5) are seen to be found on the sides or bottoms of little hollows formed by the melting of the ice, the bundles occupying slight depressions. On the bottom of the depressions was also a fine dust, cryoconite (called Kryokonite by Nordenskiöld), much of which was found with the microorganisms on the glaciers.

ANNOTATED SYSTEMATIC LIST

ALGAE

CHLOROPHYCEAE

PROTOCOCCALES

CHLAMYDOMONAS NIVALIS Wille

PLATE 6, FIGURES 42-50

Bright red spherical cells 20 μ diam. I found a great many smaller cells 7–18 μ diam., some of them with a mucilaginous envelope (pl. 6, figs. 42, 45). In sample No. 63 I found vegetative cells, several of which were 18 μ long and 11 μ diam, and which had lost their flagella. In samples Nos. 36 and 43 I saw aplanospore formation (pl. 6, fig. 47), the spore 7 μ diam. in a cell 22 μ diam. (pl. 6, figs. 46, 48). The diameter of the spherical zygospore is 24 μ (pl. 6, fig. 44), and the wall shows a netlike ornamentation. In formalin-preserved material the wall was orange red (pl. 6, fig. 49), and the inner wall layer of the zygospore was similarly colored. In these cases the orange-red color of the wall is probably caused by extraction of the color from the cell interior and subsequent staining of the wall during preservation, a phenomenon which I have noticed in nearly every case in which a red organism has been preserved in formalin. I am not describing the cell structure in detail, as it accords with the well-known published descriptions.

Today the name *Chlamydomonas nivalis* is used in a collective sense, and probably covers several different kinds of *Chlamydomonas,* each of which is a facultative cryobiont and may produce carotin and xanthophyll. While at the present there appears no possibility of distinguishing these "species" of *Chlamydomonas,* discovery of a method of keeping them in pure culture would open the path to a solution of the problem.

This typical snow alga is to be found on nearly every Alaskan snowfield.

Distribution in samples: 1, 3, 4, very rare; 14, 15, 16, not rare; 35, 36, 43-48, abundant; 60, 62, 63, 64, not rare; 73, 74, rare; 77, very rare.

CHLAMYDOMONAS SANGUINEA Lagerh.

PLATE 6, FIGURES 54-61

Large spherical or oval blood-red cells, 50–52 μ long, 36–40 μ diam., sometimes with a thick mucilaginous envelope (pl. 6, fig. 59), and with one large pyrenoid in the chromatophore. Only motionless vegetative cells were seen, and they were mostly 40–42 μ long, 22–33 μ diam., with a wall of several layers, rough on the surface (pl. 6, figs. 57, 58, 61).

This organism is differentiated from *C. nivalis* by its greater size, dark blood-red color, and the proportions of its shape. It was first described by G. Lagerheim (1892) from the red snow of Pichincha; it is a nivalis-cryobiont. The orange-red color of the cell wall of the preserved material shows in plate 6, figures 55, 57, 58, 61. Since I did not see the motile form and since the Alaskan cells are larger than the type this form could not be identified in all respects with that from Pichincha, but I am satisfied that it is the same species.

Distribution in samples: 14, rare; 43, not rare, 60, 62-64, common.

SMITHSONIMONAS, gen. nov.

Chlamydomonadearum; proximum adest ad genus Lobomonadis. Denominavi ad honorem fundatoris instituti "Smithsonian Institution," Washington. Species unicum:

SMITHSONIMONAS ABBOTII, sp. nov.

PLATE 6, FIGURES 2-21

Diameter solum cellulae 9–12 μ, longitudo tegumenti 16–21 μ et latitudo ejusdem 14–21 μ. Tegumento lateribus aut parallelis, aut adversa diverentibus; in parte superiore aut acuto, aut camerato denique aut undulato. Tegumento in superiore visu optico cyclico, superficie tegumenti, in stadio iuvenili levi; sero in aetate vetusta cum verrucis regulariter obtecta. Vegetativis cellulis semper solitariis et globosis, cum integumentis amplis campanulaeformibus obtectis; Chromatophoro globoso-cavo, vel campanulaeformi, pyrenoide centrali, stigmate globoso, nucleoque medio cellulae in positione aliquando posteriore iacente; flagellis binis antice positis, longitudine cellulae aequantibus; amylis multis; vacuolis binis. Propagatio: cum autosporis, 2–4 ibus intra vegetativam cellulam ortis. Hab. in North America in nivibus Alaskae.

Denominavi ad honorem viri illustrissimi ac clarissimi Domini Doctoris Charles G. Abbot, secretarii instituti Smithsonian, Washington, D. C., U. S. A.

Cells spherical, 9–12 μ diam., in a bell-shaped envelope 16–21 μ long, 14–21 μ diam., convex anteriorly, circular in cross section. I found several variants of the general bell-shaped form. In one we saw a shoulderlike elevation at the forward edge as in *Pteromonas protracta* (pl. 6, fig. 11). In another the usual convex front extended wedge-shaped toward the point of issue of the flagella (pl. 6, figs. 4-6, 10). The two sides of the bell-shaped form are sometimes nearly parallel, sometimes diverge considerably (pl. 6, figs. 10, 11), with many transitional individuals (pl. 6, figs. 4, 7, 9). The chromatophore is pot- or bell-shaped, with starch and a large pyrenoid in the central part. The circular stigma is placed a little behind the center of the cell; the nucleus is central. The flagella issue from the anterior end, and equal the body of the cell in length. There are two vacuoles. The envelope about the cell is smooth when young, progressively more warty when older (pl. 6, figs. 8, 12, 17-21). When this envelope thickens, the cell discharges its flagella and a resting condition sets in with an oval cell and radial ornamentation. While this occurs on the envelope, the inner cell wall becomes thinner. The protoplast becomes nearly quadrangular (pl. 6, figs. 8, 20), without any firm wall surrounding it, but connected with the envelope by thin strands of protoplasm. In spite of the changes in the cell contents the pyrenoid can be seen in some instances.

I observed autospore formation in sample No. 36 (pl. 6, fig. 4). The spherical autospores were within an envelope 16 μ long, 15 μ diam., and themselves are 6.5–8 μ diam. In the same sample there were numerous spherical cells 8–12 μ diam., which had escaped from their envelopes by the gelatinous anterior portion (pl. 6, fig. 4). The cell wall and envelope are colorless. An interesting case of aplanospore formation appeared in sample No. 35 (pl. 6, fig. 16). A spore 15 μ long and 12 μ diam. was visible in the envelope (22 μ long, 21 μ diam.). I found propagation by autospores only. Variation in the form of the organism can be seen in plate 6, figures 2-11; lacking living material for a critical analysis of the population I am classing them as variations of one species. The systematic position of this microorganism is near *Lobomonas* in the suborder Chlamydomonadeae. It differs considerably from that genus, and so I am describing it as new under the name *Smithsonimonas* after James Smithson, founder of the Smithsonian Institution in Washington. As a token of my gratitude for his help, I am naming the species after Charles G. Abbot, Secretary of the Smithsonian Institution.

This microorganism is a principal component of the red snow on Thompson Pass. It is a typical nivalis-cryobiont unknown elsewhere.

Distribution in samples: 35, 36, 43, very abundant; 62, rare; 73, 74, 77, very rare.

SCOTIELLA NIVALIS (Shuttlew.) F. E. Fritsch

PLATE 6, FIGURES 62-74

Cells 10–12 μ diam., 18–20 μ long. Form various; generally in young cells the ribs absent or only beginning to develop (pl. 6, figs. 64-72). Autospores numerous, spherical (pl. 6, figs. 64, 65). Liberation of the autospores was also seen (pl. 6, figs. 62, 63).

This appears to be the first microorganism to settle on the snowfields, and is one of the most common organisms on these fields in Alaska. It is a nivalis-cryobiont appearing frequently over the whole world.

Distribution in samples: 35, 43, 46, 48, common; 1, rare; 52, 53, very rare; 60, 62, 63, common; 70-75, not rare, 76, 77, rare.

SCOTIELLA ANTARCTICA F. E. Fritsch

PLATE 6, FIGURES 35-41

Cells 21 μ diam., 27 μ long, usually with six ribs. Sample No. 60 showed a specimen with seven ribs (pl. 6, fig. 37). In sample No. 60 I found an autosporangium 30–33 μ diam., 50 μ long (pl. 6, figs. 35, 36). In sample No. 63 cells were found with smooth walls, 50–57 μ diam., and spherical cells were found as a variant of this organism.

This alga was first described by Fritsch (1912, p. 125) from the yellow snow of the Antarctic. It is a nivalis-cryobiont known from the Western Hemisphere.

Distribution in samples: 43, rare; 60, 63, 64, not rare.

SCOTIELLA POLYPTERA F. E. Fritsch

PLATE 6, FIGURES 79, 80

Cells wide, elliptical, 24 μ diam. and 30 μ long, with longitudinal ribs. The ribs are not spiral as described by Fritsch (1912, p. 108) but straight and not undulating. It much resembles *S. polyptera* Fritsch (*Pteromonas Penardi* Gain, 1912, p. 177, pl. 3, fig. 8) described from among the mosses of antarctic Peterman Island.

It is a typical nivalis-cryobiont. I also found it in the green snow of Yellowstone National Park (Kol, 1941, p. 189).

Distribution in sample: 43, rare.

CHLOROSPHAERA ANTARCTICA F. E. Fritsch

PLATE 3, FIGURES 17-24; PLATE 5, FIGURES 1-4, 7, 9

Cells spherical, 10–25 μ diam., membrane thick and sometimes with a very thick mucilaginous envelope. Wall sometimes clearly stratified (pl. 3, fig. 17). Diameter of envelope to 50 μ, thickness of inner wall 2–3 μ. Chromatophore large, spherical, sometimes with a small pyrenoidlike body (pl. 3, fig. 18), but starch was not observed. Cells solitary or sometimes grouped (pl. 5, fig. 4). Reproduction by cell division, by zoospore formation, and by autospores. The zoosporangium, previously unreported, is 28 μ diam. and the zoospores egg-shaped (pl. 3, fig. 23).

This microorganism was first described from the yellow snow of the Antarctic by Fritsch (1912, p. 123), but so far as I know has not been seen in the interval. It is a glacialis-cryobiont, and I found it mostly on the glaciers in Alaska—only once on a snowfield.

Distribution in samples: 14-16, not rare; 19, rare; 38, 39, common.

MYCACANTHOCOCCUS CELLARIS Hansg., f. ANTARCTICA Wille

PLATE 6, FIGURES 82, 83

Cell spherical, 10 μ diam., with a thick wall ornamented with spines.

This organism was first described by Wille from the green snow of the Antarctic.

Distribution in samples: 21, 29, very rare; 35, 43, 64, rare.

MYCACANTHOCOCCUS OVALIS Gain, var. JUNEAUENSIS, var. nov.

PLATE 6, FIGURE 84

Differt a typo: mensura minore et spinis sparse praeditis.

Cells 9 μ long, 7–8 μ diam., oval, sparingly bedecked with scattered spines.

This microorganism is closely related to *M. ovalis* Gain, but differs in its smaller size.

Distribution in sample: 63, rare.

TROCHISCIA ANTARCTICA F. E. Fritsch

Cells spherical, diam. 6–14 μ, wall thick with emergences 1–2 μ long. Their aspect differs with the stage of development.

This organism was first reported from the Antarctic by F. E. Fritsch (1912, p. 123), and has not since been rediscovered. It belongs to the group of organisms existing on both permanent ice and on snowfields.

Distribution in samples: 38, 39, rare.

TROCHISCIA NIVALIS Lagerh.

PLATE 3, FIGURE 27

Cells spherical, 14–18 μ diam., the wall thickly covered with little spines.

This microorganism was first described by Lagerheim (1892) from the Andes. Since then it has been collected in the Antarctic, and was described by Fritsch (1912, p. 124). It is a mixo-cryobiont.

Distribution in samples: 38, 39, rare.

TROCHISCIA CRYOPHILA Chodat

Cell surface ornamented with blunt-ended spines 2–4 μ long, the over-all diameter being 14–24 μ.

The species *T. cryophila* was first found in Switzerland, and was described by R. Chodat (1896). It was also mentioned by Krieger from Spitzbergen. Two variants of this species were noticed in Alaskan material.

TROCHISCIA CRYOPHILA f. LONGISPINA, f. nov.

PLATE 3, FIGURES 58, 59; PLATE 5, FIGURE 10

Differt a typo: cellula spinis longioribus obtecta.

This form of *T. cryophila* has close-placed spines 4 μ long.

Distribution in samples: 38, 39, rare.

TROCHISCIA CRYOPHILA f. BREVISPINA, f. nov.

PLATE 3, FIGURE 26

Differt a typo: cellula brevioribus et sparse dispositis spinis obtecta.

This form of *T. cryophila* has sparsely placed spines 2 μ in length.

Distribution in samples: 38, 39, 52, rare.

TETRAEDRON VALDEZII, sp. nov.

PLATE 6, FIGURES 87, 88

Cellulis octogonis, membranis planis, crassis, saepe violaceis.

Proximum adest ad *T. pachydermum* (Reinsch) Hansg. sed differt ab eo: membranis planis, non concavis (uti apud *T. pachydermum*). Hab. in nivibus Alaskae.

Cells octagonal in cross section, 9 μ diam., the sides of equal length and the tips are not rounded. Wall thick, of two layers and sometimes pale violet.

This organism is close to *T. pachydermum* (Reinsch) Hansg., but differs from it in its dimensions and in that the sides are not concave. It is a typical snow alga.

Distribution in samples: 46, 47, rare; 63, very rare.

PLEUROCOCCUS VULGARIS Menegh. var. COHAERENS Wittr.

Plate 6, Figure 85

Cells 6–8 μ diam., in groups of various sizes.

This microorganism was reported by Wittrock first from the snowfields of Greenland, and since has been found in the Antarctic (Gain, 1912, p. 188) and in Yellowstone National Park (Kol, 1941, p. 190).

Distribution in sample: 35, rare.

CHAETOPHORALES

RAPHIDONEMA BREVIROSTRE Scherffel

Plate 6, Figure 27

Filaments short, to 40 μ long, of 2-8 cells, straight or curved, ends slightly pointed; cells usually shorter than broad to cylindrical, 2.5 μ diam.

This alga was collected by Prof. Istvan Györffy in Hungary in 1910, and was described by Scherffel in the same year (1910). I found it in Switzerland in 1930, and described a variety of it, *R. brevirostre* var. *canadense* in the material collected by Prof. Wm. Randolph Taylor in British Columbia. This organism is a typical nivalis-cryobiont.

Distribution in sample: 35, rare.

RAPHIDOMEMA NIVALE Lagerh.

Plate 6, Figure 86

Filaments short, to 80 μ long, of 4-8 cells, straight or slightly curved, with pointed ends; cells long, cylindrical, 2.5–3 μ diam.

This organism was first described by Lagerheim (1892) from the red snow of Ecuador. It is very common on European snowfields. It is not rare on Alaskan snowfields, but always sparingly represented by a few individuals. Like all other species of *Raphidonema* it is characteristically a nivalis-cryobiont.

Distribution in samples: 35, 43, 47, 60, rare.

STICHOCOCCUS BACILLARIS Näg., sensu stricto

Plate 6, Figure 22

Cells long cylindrical, 3 μ diam., 4–6 μ long.

This organism is very common on the snowfields of Europe. I only found it on one snowfield in Alaska. It is a typical cryoxen organism.

Distribution in sample: 47, few.

ZYGNEMATALES

ANCYCLONEMA NORDENSKIOLDII Berggren

Plate 3, Figures 1-16, 37, 38; Plate 4, Figures 1, 2, 4-10, 13-15, 20, 21; Plate 5, Figures 15, 17

Filaments very fragile, of 2–12, rarely 16 cells. A mucilage sheath is sometimes present. Cells just before division rather elongate, otherwise shorter; ends rounded. Cells 7–14 μ diam., 12–35 μ long, with 1-2 pyrenoids in a narrow, twisted parietal platelike chloroplast. Vacuolar content light to dark brownish purple, so that the whole cell appears brownish. Multiplication by cell division, first with elongation of cells and chromatophore, then division of nucleus and pyrenoids, and finally formation of the new cell wall (pl. 3, figs. 2-12). Rounding of the cell ends decreases the contact between the cells, so that the filaments become weaker as they become older. For example, a filament of eight cells will bend and separate as a rule between the fourth and fifth cells, this being the oldest point of division between cells in it.

Sexual reproduction occurs by conjugation. Zygospore spherical, 20 μ diam., with a very thick wall, formed in the conjugation tube (pl. 3, figs. 13, 16, pl. 4, figs. 5, 6). The formation of the zygospores resembles that of Roya. Germination of the zygospores results in the formation of four cells, at first spherical when liberated, later becoming somewhat elongated, and showing one pyrenoid, at which time they are 5 μ diam., 8 μ long, much below the normal size for adult cells of the species, but they may begin to divide before having reached full size.

Reproduction by asexual autospores was observed. The cell contents of the sporangia are divided into many spherical cells 2–2.5 μ diam., around each of which a cell wall is formed. After liberation these little cells begin to grow (pl. 3, figs. 14, 15; pl. 4, fig. 9).

Optimum growing conditions for *Ancyclonema* call for a pH of 5. It is a characteristic plant of permanent ice, where exclusively it is to be found. Nordenskiöld and Berggren collected this organism in July 1870 on the ice of Greenland, where it colored the surface, and in lesser quantities it has been found at various other places in the Northern Hemisphere. It was found also in Switzerland by R. Chodat and E. Kol on Mont Blanc in 1934. Gain reported it from the Antarctic (1912, p. 188) but indicated uncertainty in the determination; from the illustration I would judge that he had *Mesotaenium Berggrenii* instead.

Distribution of *Ancylonema Nordenskioldii* may be summarized: Greenland (ice bloom), Berggren, 1871, p. 295; Wittrock, 1883, p. 79. Franz Josef Land, Borge, 1899, p. 760. Spitzbergen, Lagerheim; Borge, 1911, p. 7. Norway, Nordstedt, Lagerheim. Alaska, Kol, in the present paper.

This characteristic glacialis-cryobiont I found on every Alaskan glacier. On the coast glaciers it forms long filaments and appears in great quantities, but on the interior glaciers it forms short filaments and is rare, because exclusively an ice organism (see p. 8).

In the cells of Ancyclonema I found a parasitic fungus, *Rhizophidium sphaerocarpum* (Zopf) Fischer, subsp. *cryophilum* Bérczi, which I called to that author's attention, and which is described later in this publication (p. 29).

According to Lagerheim (1892, p. 531) the irregular *Ancyclonema* cells found by Berggren in Greenland (1871, p. 295, pl. 5, fig. 11) also contained a parasitic fungus which belonged to the Chytridiaceae or to the Monadinae, but these differ entirely from the specimens from Alaska.

Distribution in samples: 14, 15, 16, 52, common; 19-23, 28, 29, 53, 54, abundant; 38, 39, very abundant (ice bloom).

MESOTAENIUM BERGGRENII (Wittr.) Lagerh., var. ALASKANA, var. nov.

PLATE 3, FIGURES 32, 39-57; PLATE 4, FIGURES 3, 11, 12, 16-19; PLATE 5, FIGURE 8

Proximum adest ad *Mesotaenium Berggrenii* (Wittr.) Lagerh. sed differt ab ea: 1, forma et dimensione cellularum; 2, chlorophoris singulis et pyrenoide singula.

Detexi et iuveni; in glacie aeterna Alaskae.

Cells single, or paired for a short time after division, cylindrical, 4–6 μ diam., 1–2 diameters long, apices broadly rounded; chloroplast single with one pyrenoid; vacuolar sap dark purple violet, sometimes rather dark brown.

The cells of this alga are far deeper in color than those of *Ancyclonema*. Sexual reproduction is by conjugation (pl. 4, fig. 11). The zygospore is regular or irregular, quadrate or subquadrate to subspherical, 16–20 μ diam., dark brown with a very thick wall (pl. 3, fig. 32). In germination four daughter cells are formed, which at first are spherical, 4 μ diam., with one chromatophore and one pyrenoid. The color of the cell sap is purple violet, though the cells appear brown (pl. 3, figs. 40, 41).

When cells are twice as long as broad they divide, beginning with the division of chloroplast and pyrenoid, then the nucleus, and only then does the new wall appear between the cells (pl. 3, figs. 42-57).

Later the young cells become rounded at the apices where they are in contact, and separate before reaching full size; the number in contact does not exceed two.

This Alaskan organism is closely related to *M. Berggrenii* (Wittr.) Lagerh., but differs in size, shape, and the presence of only a single pyrenoid and chromatophore. Like *Ancyclonema Nordenskioldii* this microorganism is a characteristic plant of permanent icefields and important in establishing ice bloom on the Columbia glacier. It is found on both coastal and inland glaciers. The species is the most frequent ice alga in the Northern Hemisphere and is also found in the Southern Hemisphere, namely, in the Andes (Lagerheim, 1892, p. 527) and Antarctica (Gain, 1912). It was first found on the icefields of Greenland, where it appeared together with *Ancyclonema*.

Distribution in samples: 12, 14–16, rare; 19–23, 28, 29, 52, not rare; 53, 54, common; 38, 39, very abundant.

CYLINDROCYSTIS BREBISSONII Menegh., oic. f. CRYOPHILA, f. nov.

Plate 3, Figures 28-31, 33, 34, 36; Plate 5, Figures 5, 6; Plate 6, Figures 30, 31

Cells cylindrical with rounded apices, 14–32 μ diam., 32–70 μ long, with a radiating chloroplast and one pyrenoid in each semicell. The zygospores are 18–25 μ diam. Reproduction is by cell division and by conjugation.

This organism is very common, appearing on icefields and snowfields, and in fresh water all over the world. In my opinion we must distinguish two biological types, the aquatic and the cryophile. The latter is a permanent element of the cryophyte vegetation. It is known from several Western Hemisphere stations: Greenland, Franz Josef Land, Spitzbergen, Siberia, Norway, Switzerland, Hungary, etc. It is a characteristic cryoxen.

Distribution in samples: 14, 16, 19, 20, 38, 39, common; 28, 29, 53, 54, not rare; 12, 52, rare.

CLOSTERIUM EXILE W. & G. S. West, var. UNICRYSTALLATUM, var. nov.

Plate 6, Figures 75, 76

Proximum adest ad *Closterium exile* W. & G. S. West sed differt ab eo: cellulae cryst allum unicum ferentes, et in dimensionem cellulae.

Cells small, moderately curved, inner margin moderately concave 6 μ diam., 36–45 μ long, cell wall smooth and colorless, chloroplast with 3-4 pyrenoids; terminal vacuoles with one moving granule. Zygospores not observed.

This organism differs from *C. exile* in shape, in its smaller size, and in the presence of but one granule in each terminal vacuole. In sample No. 54 I found one specimen with a 10-μ-thick mucilaginous envelope, which was probably evoked by adjustment to the conditions of life on ice and snow (pl. 6, fig. 75).

Distribution in samples: 54, very rare; 62, rare.

CYANOPHYCEAE

CHROOCOCCALES

GLOEOCAPSA RALFSIANA (Harv.) Kützing

Plate 5, Figure 13; Plate 6, Figures 24-26

Diameter of envelope 12–21 μ, of protoplasts 4–9 μ, the envelope stratified, with the inner layers blood red, and the outer lighter red.

This is a typical cryoxen. In sample No. 35 I found some resting stages (pl. 6, figs. 24, 25) which were 6–8 μ long and 5–8 μ diam. This organism is frequent on the snowfields of Europe.

Distribution in samples: 35, 43, 44, 47, 48, not rare; 38, 39, 54, 62, 63, rare.

GLOEOCAPSA SANGUINEA (C. Agardh.) Kützing

Cells spherical, 4–6 μ diam., with blood-red mucilage envelopes 10–12 μ diam.

This is also a characteristic cryoxen organism.

Distribution in samples: 38, 47, rare; 62, very rare.

DACTYLOCOCCOPSIS ALASKANA, sp. nov.

Plate 6, Figures 51-53

Proximum adest ad *D. irregularem* G. M. Smith, sed differt ab ea: cellulis apicibus non acutis; spiraliter non torsis, sed irregulariter undulatis; demi que habitatione, planta nivicola. Hab. in nivibus Alaskae.

Variously curved, pale bluish-green cells with blunt ends, 1–1.5 μ diam., 42–45 μ long, often several specimens interlaced.

This alga differs from *D. irregularis* G. M. Smith in the less pointed apices, lack of spiral twist, and in habitat. I found it only on Roberts Peak (sample No. 60, rare) together with snow fleas.

HORMOGONALES

OSCILLATORIA TENUIS C. Ag., var. TEKLANIKANA, var. nov.

PLATE 6, FIGURE 81

Differt a typo: dimensione, filamento solitario denique biotope.

Filaments solitary, cells 4 μ diam., one-half to three-fourths times as long as broad, apical cells simple. The difference in size, lack of grouping of the filaments, and the fact that it is a glacialis-cryobiont differeniate it from the type.

Distribution in samples: 16, rare; 20, not rare.

PHORMIDIUM ANTARCTICUM W. & G. S. West

PLATE 6, FIGURE 1

Filaments solitary, more or less curved, with the mucilaginous investment more or less definite, cells in the filaments 1–1.5 μ diam., and twice as long.

This organism was first found in fresh water in the Antarctic. It is a cryoxen type, which I found on the Columbia Glacier in fairly large quantities.

Distribution in samples: 14, 16, rare; 23, not rare; 38, 39, common.

PHORMIDIUM GLACIALE W. & G. S. West

PLATE 6, FIGURE 78

Filaments solitary, with a definite mucilage investment; cells 1.8–2 μ diam., as long as broad or longer.

This plant was first described from fresh-water samples from the Antarctic. It is a cryoxen organism.

Distribution in sample: 15, rare.

LYNGBYA MARTENSIANA Menegh. var. MENDENHALLIANA, var. nov.

PLATE 6, FIGURE 23

Differt a typo: in colore, filamento solitario et denique biotope.

The filaments, 6 μ diam., are spirally curved and have a yellowish-green color. The cells of the trichomes are 4 μ diam., shorter than wide, and show granules beside the cross-walls. There is a colorless mucous investment about the filament. The apical cell is simple.

This organism differs from the type of the species in its greater slenderness, thinner investment, yellowish color and the fact that its filaments grow dispersed on the ice.

LYNGBYA LAGERHEIMII (Möb.) Gom. var. LIEKII, var. nov.

PLATE 6, FIGURE 77

Differt a typo: in dimensione, filamento solitario et denique habitione.

Denominavi ad honorem illustrissimi ac clarissimi Domini Directoris of Mount McKinley National Park, Harry J. Liek.

Filaments single, more or less spirally curved, 4 μ diam. Mucous investment colorless. Apical cell simple; transverse walls granulated.

This plant differs from the type of the species in its larger filaments, granulated cross-walls, and habitat as a glacialis-cryobiont.

I have named this species after Harry J. Liek, Superintendent of Mount McKinley National Park, 1936.

Distribution in sample: 15, rare.

FUNGI

CHIONASTER BICORNIS, sp. nov.

PLATE 6, FIGURES 32-34

Cellulae constanter duo cornua nunquam pluria ferentes.

Cells with two long, pointed horns 4 μ wide and 60 μ long, and a thick cell wall.

This plant resembles *C. nivalis* (Bohl.) Wille, except in the constant presence of two pointed horns. I have not seen any developmental stages, such as I saw for *C. nivalis* on the snowfields of the Retyezát, Hungary, on which basis I placed that plant among the fungi. It is a characteristic snow organism.

Distribution in samples: 16, 60, rare.

RHIZOPHIDIUM SPHAEROCARPUM (Zopf)[4] Fischer,[5] subspecies CRYOPHILUM Laszló Bérczi, subsp. nov.

TEXT FIGURES 4 AND 5

Proximum adest ad *R. sphaerocarpum,* sed differt ad hoc: quo rationem vivendi attinet. Etenim in glacie et in tali planta inveniri protest, auali *R. sphaerocarpum* non adhaeret.

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[4] Zopf, W., Zur Kenntnis der Phycomyceten, I. Zur Morphologie und Biologie der Ancylisteen und Chytridiaceen, zugleich ein Beitrag zur Phytopathologie. Nova Acta Kaiserl. Leop. Carol. Deutsch. Acad. Naturf. vol. 48, No. 4, pp. 141-236, 1884.

[5] Fischer, A., Die Pilze Deutschlands, Oesterreichs und der Schweiz. Abt. 4: Phycomycetes. Leipzig, 1892.

I called Mr. Bérczi's attention to a parasitic fungus which I had observed in the cells of *Ancylonema Nordenskioldii* collected from the Columbia Glacier.

The sporangia of this chytrid are extramatrical and they lie close together on the vegetative cells of the *Ancylonema*. Young, ripe sporangia are spherical, 7–10 μ diam., with a rhizoid slight in development and ramification. The zoospores are spherical, 3 μ diam., and they emerge from the sporangium through a large apical pore. The new species belongs to the group *Unipora* of the section *Globosa*

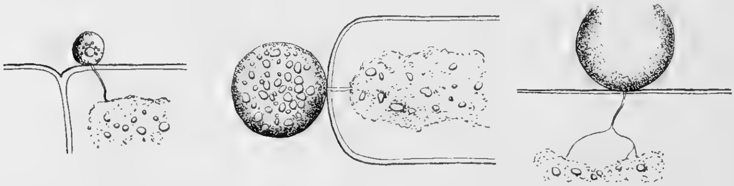

FIG. 4.—*Rhizophidium sphaerocarpum* (Zopf) Fischer, subspecies *cryophilum* Laszló Bérczi, new subspecies.

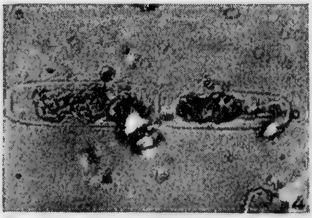

FIG. 5.—*Rhizophidium sphaerocarpum* (Zopf) Fischer, subspecies *cryophilum* Laszló Bérczi, new subspecies.

of *Rhizophidium*. While closely related to *R. sphaerocarpum* I could not find the type of discharge characteristic of that species, and so am unwilling to consider it identical. I know of no fungi reported as parasites on *Ancylonema*. The new subspecies is a typical cryobiont.

Distribution in samples: 52, rare; 38, 39, not rare.

SUMMARY

My cryobiological research on the snowfields and glaciers of Alaska during the summer of 1936 indicates that these show a unique society of cryomicroorganisms. This is the first research on the cryoorganisms and their environment that has been carried out in North America.

The range of pH of the snowfields is 4.5-6.5, and of the ice surface 5-7. Besides the range of surface variation, differences with depth also appear down to 1 foot. It is also influenced by the proximity of rocks, the dust from them falling on the surface. From the point of view of their chemical character we may distinguish calcitroph and silicotroph environments, and from their physical character snow, firn, and ice.

The plants which grow in these places may be designated snow- or nivalis-cryobionts (planta nivicola), ice- or glacialis-cryobionts (planta glacicicola), and mixo-cryobionts or cryoxen.

Three very interesting natural phenomena appear in the cryo-environments of Alaska: The red-pepper-colored snow on Thompson Pass, the brown-violet ice bloom on the Colombia Glacier, and the colonies of snow fleas on Gastineau Peak. The red snow is caused by *Chlamydomonas nivalis, C. sanguinea, Smithsonimonas Abbotii,* and *Scotiella nivalis,* with 10 other organisms in smaller numbers. The purple-brown bloom is caused by *Ancyclonema Nordenskioldii* and *Mesotaenium Berggrenii* var. *alaskana,* with nine other kinds of organisms in minor association and not affecting the color. This is the first American record of ice bloom.

Altogether, 32 cryomicroorganisms are listed from Alaska (Algae: Chlorophyceae 22, Cyanophyceae 8. Fungi: 2). I describe as new: *Smithsonimonas,* new genus; *S. Abbotii, Tetraedron valdezii, Dactylococcopsis alaskana, Chionaster bicornis,* new species; *Mycacanthococcus ovalis* var. *juneauensis, Mesotaenium Berggrenii* var. *alaskana, Closterium exile* var. *unicrystallatum, Oscillatoria tenuis* var. *teklanikana, Lyngbya Lagerheimii* var. *Liekii, L. Martensiana* var. *mendenhalliana,* new varieties; *Rhizophidium sphaerocarpum* subsp. *cryophilum* Laszló Bérczi, new subsp.; *Trochiscia cryophilum* f. *longispina,* f. *brevispina, Cylindrocystis Brebissonii* oic. f. *cryophila,* new forms. Among these microorganisms were 12 nivalis-cryobionts (snow algae), 10 glacialis-cryobionts (ice organisms), 3 mixo-cryobionts, and 4 cryoxen. These include organisms such as had previously been considered as restricted to Northern, Western, Southern, or Eastern Hemispheres. From this we may conclude that the distribution of cryovegetation depends on the environment and geographical position as well. It is evident that the Alaskan cryovegetation is varied and rich.

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EXPLANATION OF PLATES

PLATE 1

(Photographs by E. Kol.)

FIGS. 1, 2. Ice mounds of Columbia Glacier, at a distance of about 1 mile from the ocean, covered with brownish ice bloom.

FIGS. 3, 5. A dark brown spotted algal mass consisting principally of *Ancyclonema* filaments spread over the surface of the ice, mostly at the bottom of the holes melted in the ice.

FIG. 4. Icefield covered with *Ancyclonema* and *Mesotaenium*.

FIG. 6. Ice mounds covered with ice bloom.

FIG. 7. Photograph of Columbia Glacier, taken from Columbia Bay.

PLATE 2

FIG. 1. Silicotroph snowfield with red snow, lying below Thompson Pass.

FIG. 2. Snowfield covered with pinkish snow, below Thompson Pass. The edge of the melting snow is covered with blackish dust.

FIG. 3. Silicotroph snowfield in the vicinity of Thompson Pass.

FIG. 4. Snowfield lying at the head of the Savage River, with very poor cryovegetation, covered with much refuse and dust.

FIG. 5. Silicotroph snowfield with red snow 2 feet deep on Thompson Pass.

FIGS. 6, 7. Snowfields at the head of the Savage River, with very poor vegetation.

FIGS. 8, 9. Teklanika Glacier.

Plate 3

FIGS. 1–16. *Ancylonema Nordenskioldii* Berggr., normal filaments and cell division. 1, normal filament after cell division (× 1,000); 2–12, first division of the young cells after the germination of the zygospore; 2, 4, the young cell has one small pyrenoid (× 1,000); 3, 5, the pyrenoid becomes larger (× 1,250); 6–10, division of the pyrenoid and the chloroplast (× 1,000); 11, 12, formation of the new cell wall (× 1,000); 13, conjugation (three filaments) (× 1,000); 14, 15, liberation of autospores (× 1,000); 16, conjugation (× 1,000).

FIGS. 17–24. *Chlorosphaera antarctica* Fritsch. 17, a cell with very thick and stratified membrane (× 750); 18, a cell with a pyrenoidlike round body in the chloroplast (× 660); 19, 20, cells with a chloroplast without the pyrenoidlike body; 19, (× 660); 20, (× 1,250); 21, a cell with a wide mucilage envelope (× 700); 22, a cell with segregated masses of fat (× 700); 23, zoosporangium—formation of zoospores (× 1,000); 24, cell division (× 1,000).

FIG. 25. *Scotiella nivalis* (Shuttlew.) Fritsch.

FIG. 26. *Trochiscia cryophila* f. *brevispina* Kol (× 700).

FIG. 27. *Trochiscia nivalis* Lagerh. (× 1,300).

FIG. 28. *Cylindrocystis Brebissonii* Menegh. f. *cryophila* Kol, abnormal cell division (× 660).

FIG. 29. *Cylindrocystis Brebissonii* Menegh. f. *cryophila* Kol, early conjugation stage (× 1,000).

FIGS. 30, 31, 33, 34. *Cylindrocystis Brebissonii* f. *cryophila* Kol, zygospores (× 1,000).

FIG. 32. *Mesotaenium Berggrenii* var. *alaskana* Kol, zygospore (× 1,000).

FIG. 35. *Ancyclonema Nordenskioldii,* germination (× 1,300).

FIG. 36. *Cylindrocystis Brebissonii* f. *cryophila* Kol, normal cell (× 900).

FIGS. 37, 38. *Ancyclonema Nordenskioldii.* 37, beginning of fragmentation (× 750); 38, zygospore (× 1,500).

FIGS. 39–41. *Mesotaenium Berggrenii* var. *alaskana* Kol. Different stages of the opening of the zygospore (× 1,000).

FIGS. 42–57. *Mesotaenium Berggrenii* var. *alaskana* Kol (× 1,300). Different stages of division of the young cells, after the germination of the zygospore. 42–44, young cells with one pyrenoid; 45–51, division of the chloroplast and pyrenoid; 53, 54, formation of the new cell wall between the young cells; 55–57, separation of the two young cells.

FIGS. 58, 59. *Trochiscia cryophila* f. *longispina* Kol (× 1,000).

Plate 4

(Photomicrographs by E. Kol.)

FIGS. 1, 2, 7, 8. *Ancyclonema Nordenskioldii,* normal filaments (× 400).

FIG. 3. *Mesotaenium Berggrenii* var. *alaskana* Kol, zygospore (× 800).

FIG. 4. *Ancyclonema Nordenskioldii,* zygospore (× 600).

FIGS. 5, 6, 13. *Ancyclonema Nordenskioldii,* conjugation.

FIG. 9. *Ancyclonema Nordenskioldii,* liberation of autospores.

FIG. 10. *Ancyclonema Nordenskioldii,* young plant.

FIGS. 11, 12, 16–19. *Mesotaenium Berggrenii* var. *alaskana* Kol. 11, conjugation (× 800); 12, 17, 18, 19, zygospores; 16, normal cell (× 800).

FIGS. 14, 15, 20, 21. *Ancyclonema Nordenskioldii.* 14, 15, beginning of the fragmentation of the filament; 20, normal filament; 21, division of the cells of the filament.

PLATE 5

(Photomicrographs by E. Kol.)

FIGS. 1–4, 7, 9. *Chlorosphaera antarctica* Fritsch. 1, 2, cells with thick cell wall and with pyrenoidlike body on the chloroplast (× 800); 3, a cell with segregated masses of fat (× 800); 4, a group of cells with mucilage envelope (× 160); 7, 9, a cell with very thick mucilage envelope (× 400).

FIGS. 5, 6. *Cylindrocystis Brebissonii* f. *cryophila* Kol. 5, (× 600); 6, (× 800).

FIG. 8. *Mesotaenium Berggrenii* var. *alaskana* Kol, zygospore.

FIG. 10. *Trochiscia cryophila* f. *longspina* Kol (× 800).

FIG. 11. *Trochiscia cryophila* var. *brevispina* Kol (× 800).

FIGS. 12, 14. *Trochiscia nivalis.* 12, (× 400); 14, (× 800).

FIG. 13. *Gloeocapsa Ralfsiana* (Harv.) Kütz (× 800).

FIGS. 15, 17. *Ancyclonema Nordenskioldii,* normal filaments.

[Reference to fig. 16 not supplied by author.]

PLATE 6

FIG. 1. *Phormidium antarcticum* W. & G. S. West (× 666).

FIGS. 2–21. *Smithsonimonas Abbotii* Kol. 2, vegetative cell before the formation of the warts (× 833); 3, vegetative cell (× 500); 4, two autospores in the autosporangia (× 666); 5–7, different vegetative cells; 8, the beginning of the formation of the warts on the surface of vegetative cell (× 833); 9–11, different forms of the envelope of the vegetative cells; 12, the envelope covered by warts, resting stage (× 666); 13–15, liberated autospores (× 500); 16, formation of aplanospore (× 666); 17–21, resting stages, decorated by warts (× 666).

FIG. 22. *Stichococcus bacillaris* Näg. (× 666).

FIG. 23. *Lyngbya Martensiana* var. *mendenhalliana* Kol (× 500).

FIGS. 24–26. *Gloeocapsa Ralfsiana* (Harv.) Kütz. 24, 25, resting stages (× 666); 26, (× 333).

FIG. 27. *Raphidonema brevirostre* Scherffel (× 500).

FIGS. 28, 29. *Raphidonema nivale* Lagerh. (× 333).

FIGS. 30, 31. *Cylindrocystis Brebissonii* f. *cryophila* Kol (× 500). 31, apical view.

FIGS. 32–34. *Chionaster bicornis* Kol. 32, (× 333); 33, 34, (× 666).

FIGS. 35–41. *Scotiella antarctica* Fritsch. 37, an irregular individual with seven ribs (× 500); 38, 39, liberated autospores (× 250); 35, 36, autosporanguim (× 333); 40, resting stages (× 500); 41, resting stage (× 500).

FIGS. 42–50. *Chlamydomonas nivalis* Wille. 42, (× 333); 43, (× 500); 45, with very thick mucilage envelope (× 500). All motionless spherical cells. 44, zygospore (× 500); 46–48, aplanospore (× 500); 49, 50, cells with thick cell wall (× 500).

FIGS. 51–53. *Dactylococcopsis alaskana* Kol. 51, 52, (× 500); 53, (× 166).

FIGS. 54–61. *Chlamydomonas sanguinea* Lagerh. (× 333). Cells preserved in formalin. 57, 58, 61, the surface of the cell wall rough; 59, with very thick mucilage envelope.

FIGS. 62–74. *Scotiella nivalis* (Shuttlew.) Fritsch. 62, 63, autosporangium; 62, (× 666); 63, (× 500); 64, 65, 73, liberated autospores (× 666); 66–72, different stages of the development (× 500); 74, the ribs are developed (× 666); 72, (× 666).

FIGS. 75, 76. *Closterium exile* var. *unicrystallatum* Kol. 75, (× 333); 76, (× 500).

FIG. 77. *Lyngbya Lagerheimii* var. *Liekii* Kol (× 500).

FIG. 78. *Phormidium glaciale* W. & G. S. West (× 500).

FIGS. 79, 80. *Scotiella polyptera* Fritsch. (× 500).

FIG. 81. *Oscillatoria tenuis* var. *teklanikana* Kol (× 500).

FIGS. 82, 83. *Mycacanthococcus cellaris* f. *antarctica* Wille (× 500).

FIG. 84. *Mycacanthococcus ovalis* var. *juneauensis* Kol (× 666).

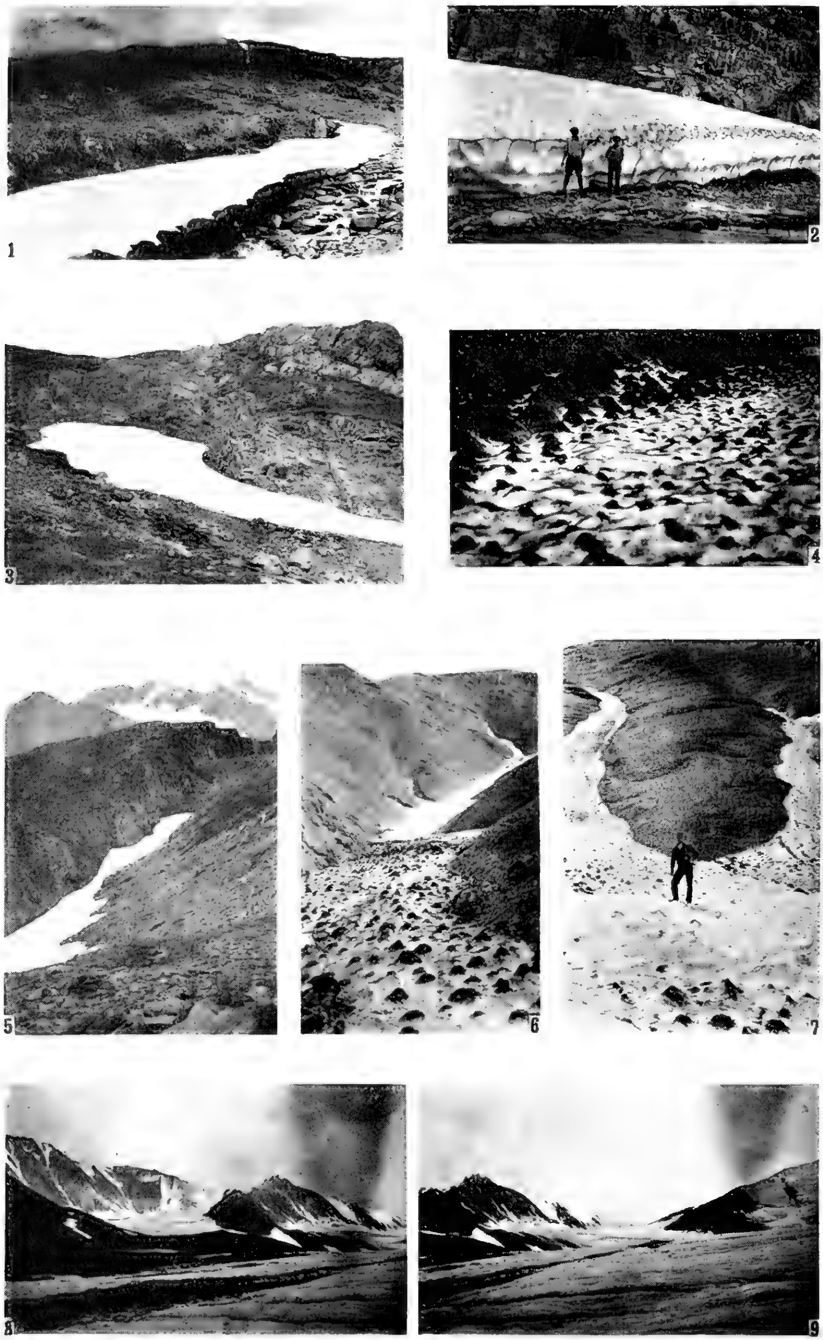
FIG. 85. *Pleurococcus vulgaris* β *cohaerens* Wittr. (× 666).

FIG. 86. *Raphidonema nivale* Lagerh. (× 666).

FIGS. 87, 88. *Tetraedron valdezii* Kol (× 666).

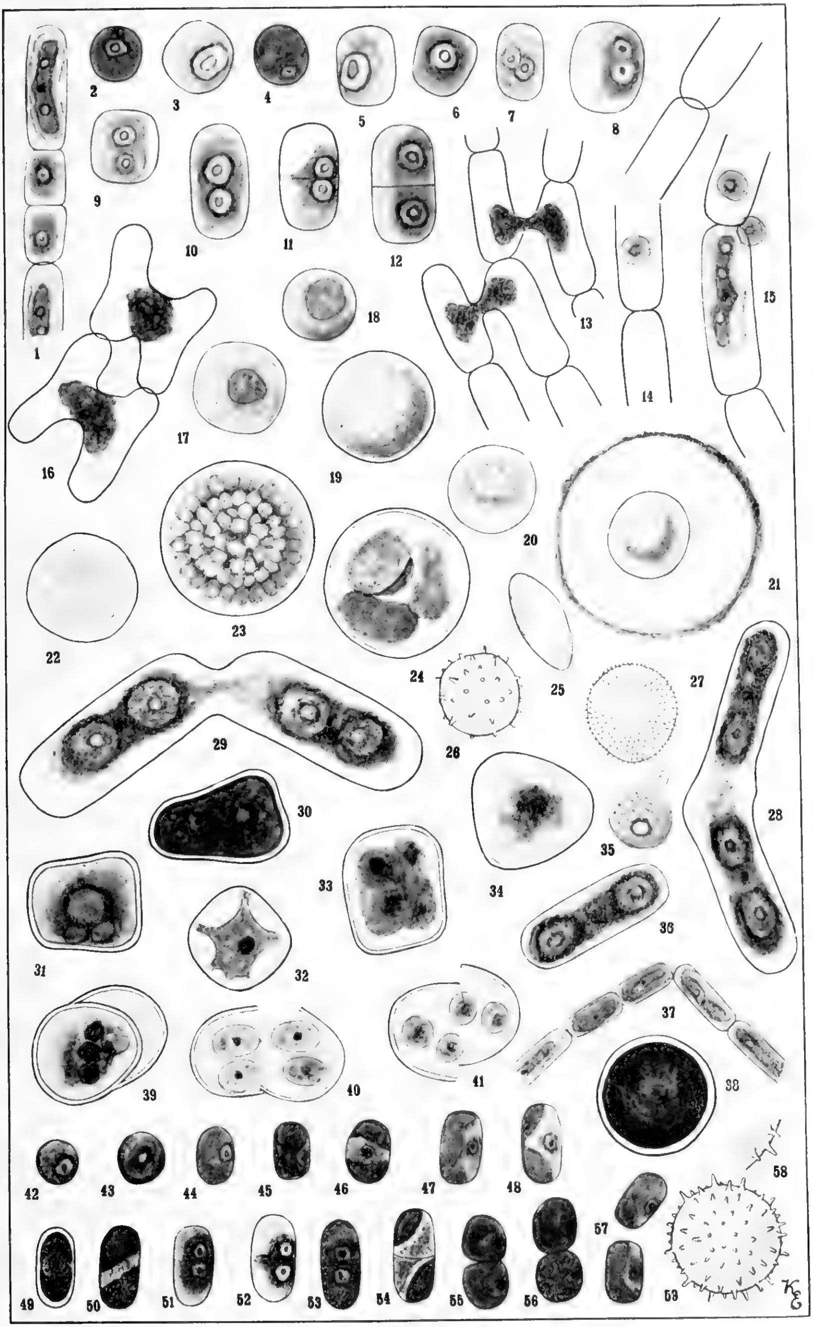
ICEFIELDS AND GLACIERS OF ALASKA

(For explanation, see p. 33.)



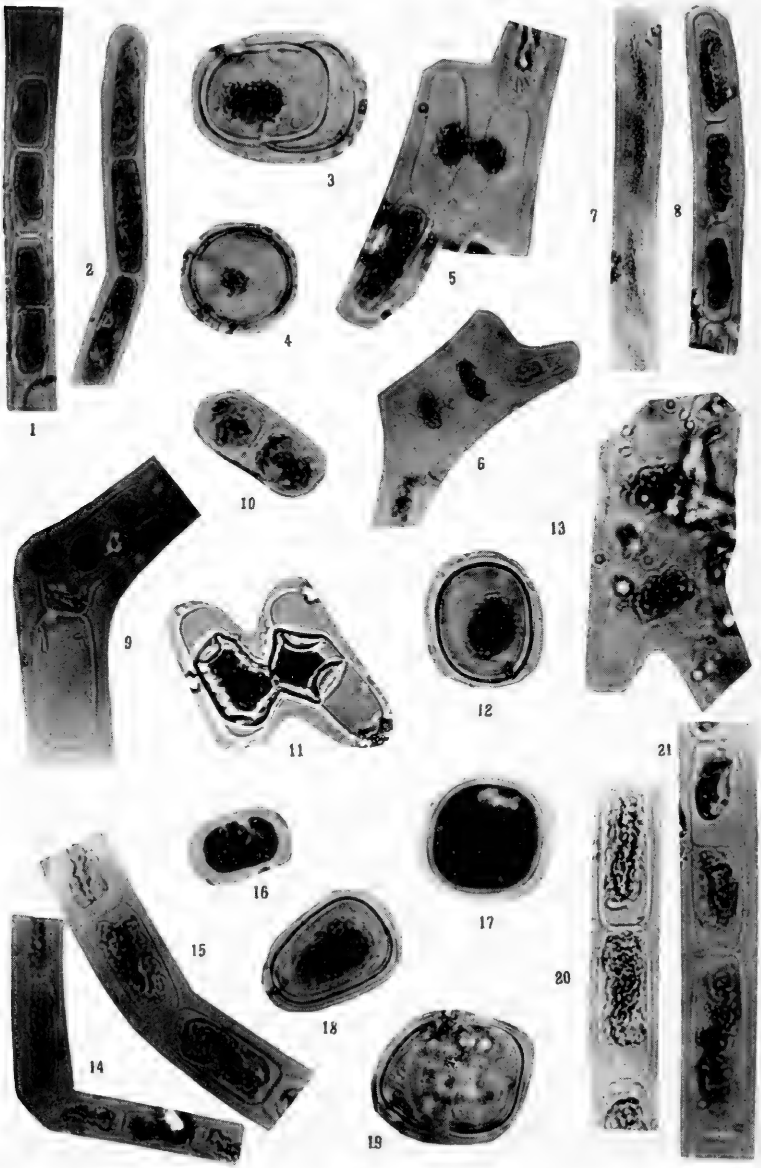
SNOWFIELDS AND GLACIERS OF ALASKA

(For explanation, see p. 33.)



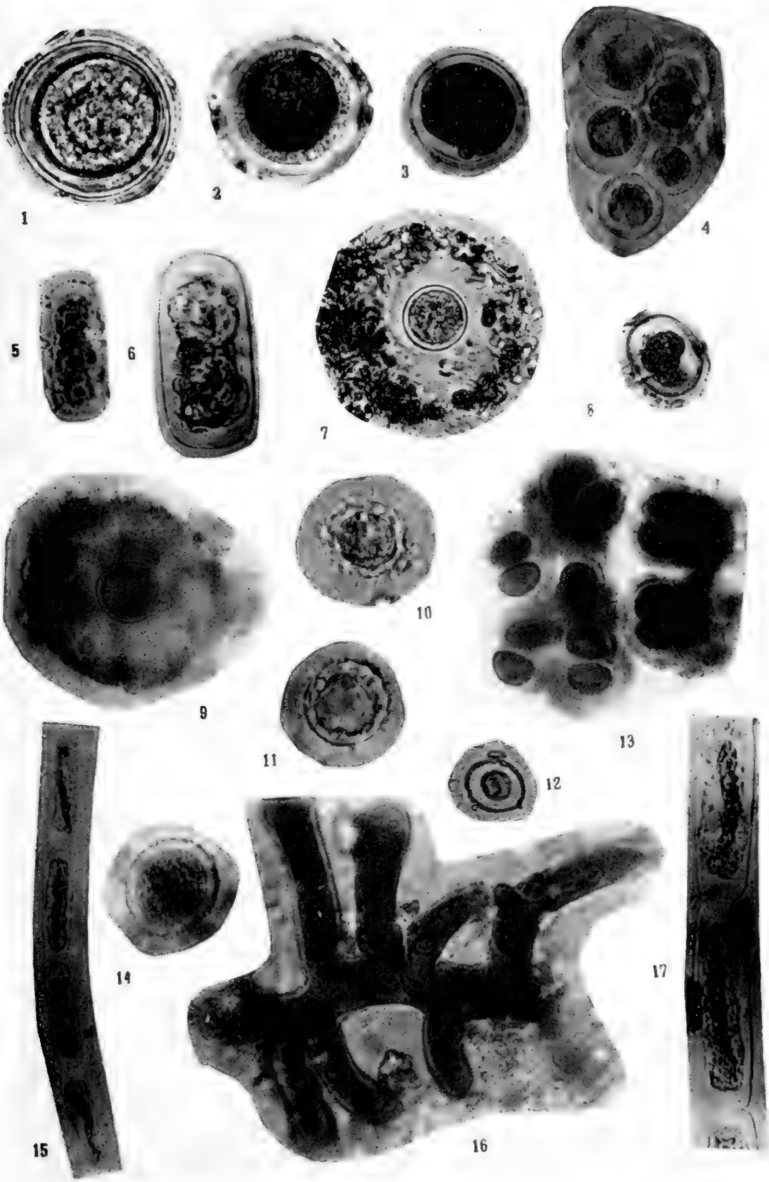
CRYOVEGETATION OF ALASKA

(For explanation, see p. 34.)



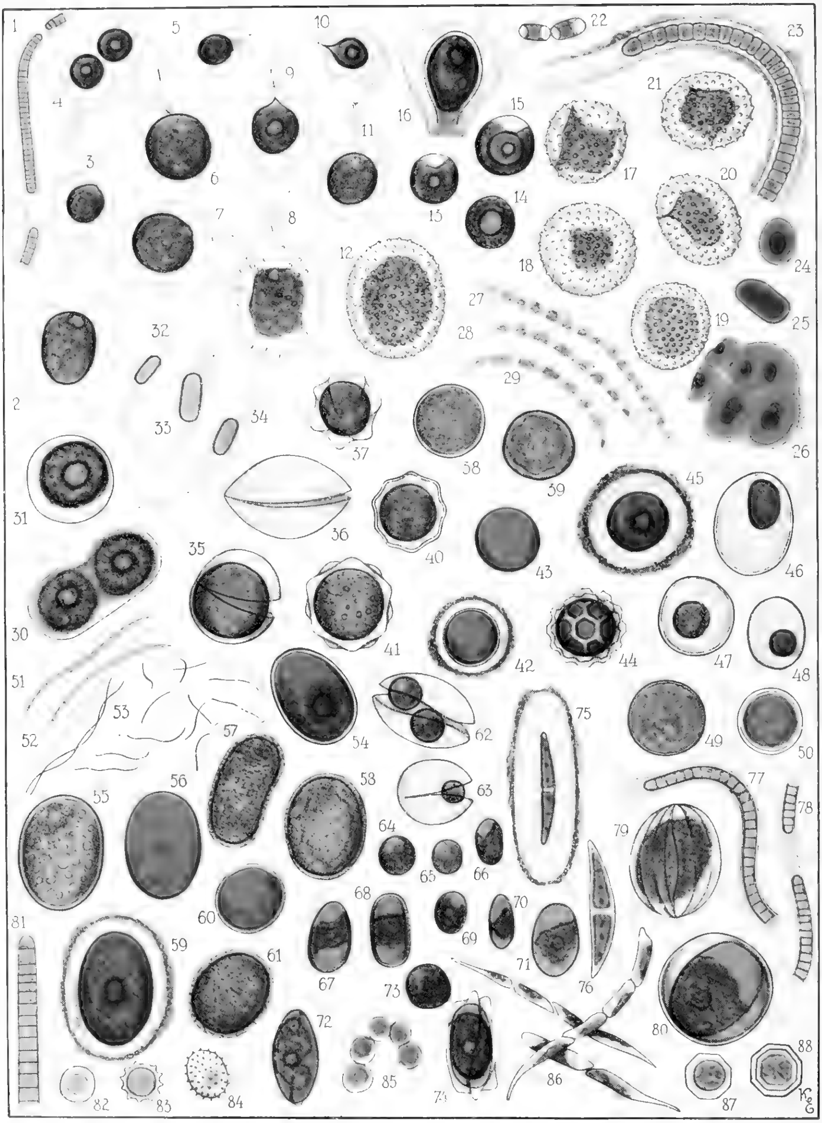
CRYOVEGETATION OF ALASKA

(For explanation, see pp. 34-35.)



CRYOVEGETATION OF ALASKA

(For explanation, see p. 35.)



CRYOVEGETATION OF ALASKA

(For explanation, see pp. 35-36.)

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 101, NUMBER 17

DEVELOPMENTAL PHYSIOLOGY OF THE GRASS SEEDLING

I. INHIBITION OF THE MESOCOTYL OF AVENA SATIVA BY CONTINUOUS EXPOSURE TO LIGHT OF LOW INTENSITIES

(WITH ONE PLATE)

BY
ROBERT L. WEINTRAUB
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INTRODUCTION

It is well known that growth of the mesocotyl of various grass seedlings is markedly influenced by illumination. Nevertheless, our understanding of the mechanism of this phenomenon is very fragmentary, despite the numerous studies that have been made since the effect was first noted by Cassini (1820) more than a century ago. One of the many aspects of the problem about which further quantitative information is desirable is that of the spectral effectiveness of the radiant energy causing the growth inhibition. The present experiments have been undertaken as a first approach toward the determination of the action spectrum for mesocotyl inhibition.

Review of the literature[1] leads to the conclusion that, in general, there has been inadequate appreciation of the dependence of the effects of radiant energy upon its intensity and spectral distribution, upon the duration of the irradiation, upon the developmental stage of the plant and possibly also upon other environmental and internal conditions. The present report is concerned exclusively with the results produced by light of known intensity and quality, applied throughout the entire period of growth of the mesocotyl. As far as the authors are aware the only comparable published experiments are those of Avery, Burkholder, and Creighton (1937).

EXPERIMENTAL PROCEDURE

Oats of the variety Markton[2] were used. After removal of the glumes the dormant grains were planted individually in small test

[1] An analysis of the literature relating to the physiology of the grass mesocotyl is being prepared for separate publication.

[2] The seeds were kindly supplied by T. R. Stanton, of the U. S. Department of Agriculture.

tubes (about 1 cm. in diameter and 7 cm. long) on slants of 1 percent agar made up with tap water. The seeds rapidly absorb water from the agar, and the seedlings develop very uniformly. This technique is convenient for irradiation studies in that the seeds, which have been found to be insensitive to light during the first few hours of germination, can be placed in the desired experimental environment within a few minutes after planting. No further attention or manipulation of the plants is required until the conclusion of the experiment when the seedling organs are measured. An 8-day growth period was chosen,

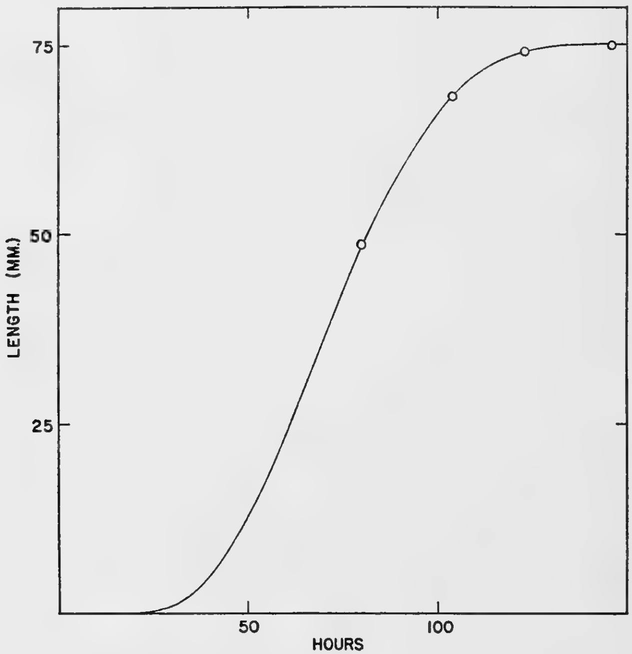

FIG. 1.—Growth curve of mesocotyl in complete darkness at 27.5° C.

since at the temperature used the mesocotyl and coleoptile have completed their growth in this length of time (see fig. 1).

The growth chamber consisted of a galvanized iron box divided into 4 compartments into each of which was placed a set of 25 to 30 culture tubes in a 400-ml. beaker. A layer of water on the floor of the growth chamber served to maintain the humidity of the air at saturation. The open top of the box was provided with flanges so that each compartment could be covered with an individual filter, without the light passing from one compartment to another. In practice three different light intensities were studied in a single experiment, the fourth group of plants serving as a dark control.

In order to provide a graded series of intensities at each wave length, light screens were made up of layers of colored cellophane enclosed between two sheets of glass. Various colors of cellophane are available and by choosing the appropriate number of layers almost any desired series can be obtained. The transmissions of these filters were determined for the particular spectral bands in which they were employed.

The spectral regions studied were isolated by means of two quartz-prism monochromators arranged in series. The wave-length spread of these bands was determined visually with a spectroscope.

The radiation source was a 1,000-lumen, 6.6-ampere Mazda street-series lamp operated from a 115-volt a.c. line, through a transformer, at 18 volts and 6 to 7 amperes. Line-voltage fluctuations were minimized by means of a voltage regulator. Gradual drifts in current due to ageing of the lamps could be detected by a sensitive ammeter connected in the circuit; this was read several times during each day and, when necessary, the current was adjusted by means of a variable resistor. The variation in current was never greater than a few hundredths of an ampere during a day and in many experiments no change could be observed over a period of several days.

The lamp was placed outside the dark room containing the growth chamber and the double monochromator so that only the radiant energy which passed through the instrument reached the plants. The beam of light from the exit slit was reflected downward onto the seedlings by means of a 45° silvered glass mirror.

The box containing the plants was mounted on a turntable rotated by a synchronous motor at 2 revolutions per minute, so that each set of plants traversed the light beam 4 times each minute. The rotation was considered necessary since the two sides of the box received light of slightly different wave-lengths owing to the widths (85 to 130 A.) of the bands isolated.

The intensities incident on the plants were calculated by means of the inverse-square law. This is justified since, at the distances used, the exit slit (1 by 10 mm.) can be considered as a point source without significant error. The relation between the intensity at the slit and that at 10 cm. distance from the slit was determined initially; from the values of this factor, of the length of the light path from the exit slit to the seeds, of the reflection loss due to the mirror and of the transmission of the filters, the intensity at the level of the seeds could be calculated. It is realized that an error is introduced through the use of vertical illumination, since, owing to the growth of the shoots, the effective intensity changes slightly during the course of the experiment and is actually somewhat greater than that at the seed level. This error is smaller than the uncertainties in other measurements, however, and may be neglected.

Except for the experiments at 6600 A., the radiation intensity at the exit slit was measured by a vacuum thermocouple connected with a Leeds and Northrop type-HS galvanometer. The thermocouple and galvanometer combination were calibrated against a National Bureau of Standards standard of radiation, correction being made for the differences in wave-length distribution of the standard lamp and of the spectral regions isolated by the double monochromator. For the experiments at 6600 A. a barrier-type photocell ("Electro-

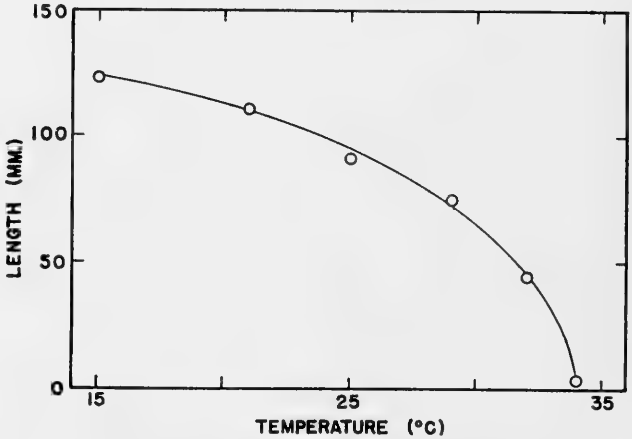

FIG. 2.—Influence of temperature on final lengths of mesocotyls grown in complete darkness.

cell") and high-resistance galvanometer, which had been calibrated against the thermocouple at this wave length, were used.

The relationship between the effects of temperature and of radiant energy on the development of the grass seedling is a subject that would appear to justify detailed investigation. Some preliminary results of such a study, shown in figure 2, emphasize the necessity of close control of temperature if comparisons are to be made among plants grown at different times. As a check on the adequacy of the temperature regulation in the present work a continuous thermograph record was obtained for each run. In the majority of these experiments the temperature was maintained at $27.5 \pm 0.2°$ C. In a few the temperature varied from this value over a 1- to 2-degree range. For this reason the length measurements of the plants in all the experiments are not strictly intercomparable. However, since there is no evidence that the action spectrum is affected by small temperature differences, the values relative to the dark controls included in each run are comparable. The results, therefore, have been expressed in relative terms.

RESULTS

The mesocotyls of seedlings that are illuminated continuously from the time of planting do not attain as great a final length as do those grown in darkness. The extent of the growth inhibition is dependent upon the intensity and quality of the light. The results for a series of wave-length bands are summarized in table 1. These data are plotted in figure 3, using a logarithmic scale for the intensities; the curves were fitted by the method of least squares.

It will be seen that the inhibition is proportional to the logarithm of the intensity and that the slopes of the curves for different wave lengths are substantially equal. The curve for 7700 A. has been arbitrarily drawn parallel to the others since only the highest intensity employed was sufficient to cause measurable inhibition. Attention should be directed also to the great range of intensities over which the inhibitory effects are produced and to the existence of distinct threshold values for each wave-length band.

The action spectrum is obtained by plotting the reciprocal of the intensity required to produce a given effect against the wave length. On the assumption that the number of quanta required for this response is the same at all wave lengths, comparison is more properly made on a quantum basis. This has been done in figure 4, although the correction is relatively small (table 2). The action curve shows a sharp peak at about 6600 A. and indication of a second maximum in the neighborhood of 6200 A.

DISCUSSION

The experiments here reported were undertaken to furnish a working curve as a basis for further investigation. The present results are to be regarded as constituting merely a first approximation to the action spectrum for mesocotyl inhibition since data are available for only seven relatively widely spaced wave lengths. Although these points have been connected by a curve, it is obvious that nothing is actually known of the intermediate regions. Other methods of study which are less time-consuming can be employed to obtain additional points on the curve and it is hoped to present the results derived by such technique at a later date.

TABLE 1.—*Light intensity and mesocotyl inhibition*

Wave-length band (A.)	Intensity at seed (ergs/mm.²/sec.)	Inhibition (%)
4250-4360	618,000. $\times 10^{-9}$	66.9
	59,000.	45.7
	11,200.	30.1
	8,520.	33.2
	1,070.	5.4
	154.	0
	19.2	0
	2.78	0
5445-5552	78,000.	61.6
	75,700.	60.6
	22,000.	47.5
	21,300.	49.3
	13,100.	48.1
	6,200.	38.9
	6,010.	39.4
	3,950.	33.8
	1,120.	20.0
	1,040.	22.3
	312.	9.4
	82.6	0
	6.84	0
6155-6240	20,600.	67.3
	4,810.	60.3
	1,450.	46.9
	337.	33.1
	101.	23.7
	23.6	6.6
6435-6550	3,720.	57.6
	3,200.	59.7
	192.	30.1
	166.	29.6
	10.1	3.9
6545-6645	4,450.	69.2
	4,360.	68.7
	1,600.	62.0
	788.	57.0
	234.	43.4
	230.	44.8
	84.2	30.0
	41.6	26.6
	4.43	5.8
7030-7160	2,300.	66.9
	858.	35.4
	32.2	4.5
7640-7760	74,000.	11.0
	7,250.	0
	708.	0

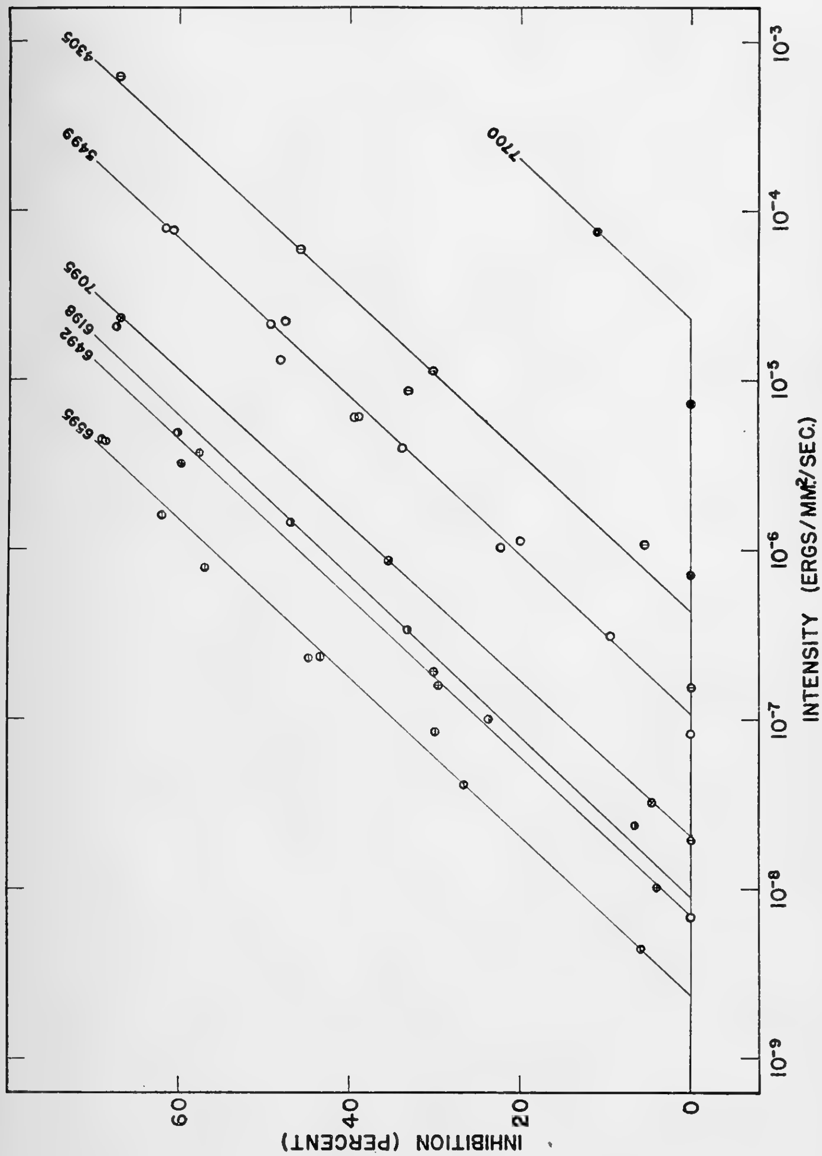

Fig. 3.—Effect of intensity on inhibition of mesocotyl growth by various wave lengths of light.

The true position of the peak shown at 6600 A. may possibly be at a somewhat longer wave length. There is some uncertainty also as to the exact location of the suggested second maximum.

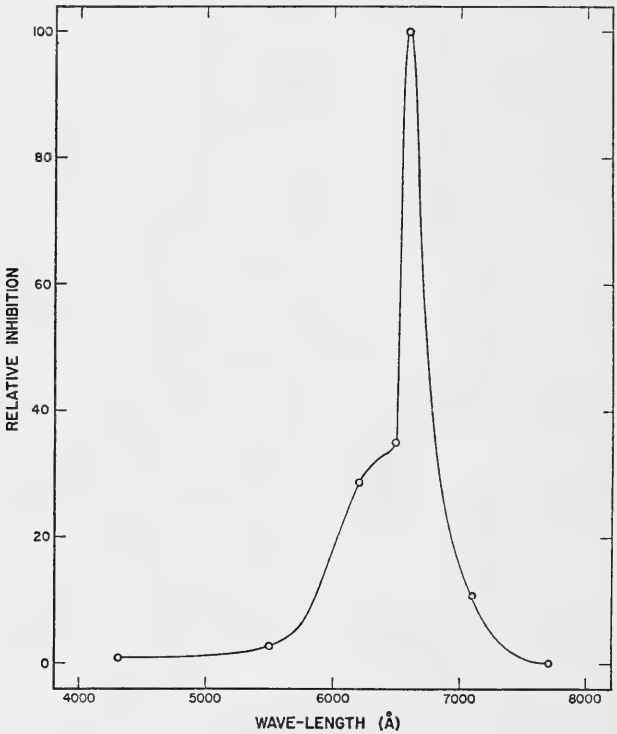

FIG. 4.—Spectral effectiveness curve for mesocotyl inhibition.

TABLE 2.—*Relative spectral effectiveness for mesocotyl inhibition*

Wave length (A.)	Relative effectiveness (Compared on energy basis)	Relative effectiveness (Compared on quantum basis)
4305	0.6	0.8
5499	2.2	2.4
6198	26.7	28.4
6492	34.0	34.5
6595	100.	100.
7095	11.6	10.8
7700	0.01	0.009

The absorption spectrum of the photoreceptive substance involved in the inhibition of growth by light may be expected to show a general resemblance to the action spectrum, provided that other pigments are not present also. Since marked growth effects may be obtained by illumination of dark-grown seedlings for periods of only a few seconds, the light-sensitive system appears to be present in the completely etiolated seedling. Extracts of etiolated oats seedlings show absorption bands with maxima at about 625 and 660 mμ. Corresponding bands, at somewhat longer wave lengths, can be observed also on first illumination of etiolated oats leaves. Preliminary study has indicated that these bands are due to at least two substances; these might conceivably be the pigments which have been designated as protochlorophyll and chlorophyllogen. It is not possible to state, as yet, whether more than one pigment participates in the photoreceptive mechanism of mesocotyl inhibition.

The dark-grown oats seedling contains also relatively large amounts of carotenoid pigments which absorb strongly in the blue portion of the spectrum, where the provisional action spectrum shows no maxima. However, since the absorption by these yellow pigments might be expected to diminish the effectiveness of the shorter visible wavelength region and since the mesocotyl growth is in fact affected by light of such wave lengths, it seems very likely that the photoreceptive pigment possesses absorption bands in this region also.

The growth of the mesocotyl in darkness is the result of two processes: cell division and cell elongation. The data of Avery, Burkholder, and Creighton (1937) suggest that at low light intensities it is the process of cell multiplication that is inhibited, whereas cell elongation is affected only by higher intensities. If experiments such as those reported above are extended to higher intensities a more or less sharp inflection is found in the inhibition-intensity curves. It may be inferred that at intensities below this knee (i.e., for the region shown in the curves of figure 3) only cell division is influenced, whereas at higher intensities inhibition of cell stretching is involved also. Experiments designed to furnish cytological evidence bearing on this suggestion are now in progress. If the mechanism should prove to be as outlined the action spectrum determined at the lower intensities represents chiefly the inhibition of cell multiplication. It might be possible, by studies at higher intensities, to determine also the action spectrum for the cell-extension process.

The authors take pleasure in acknowledging the cooperation in many ways of the other members of the Division of Radiation and Organisms and the technical assistance of E. R. Brydon and O. R. Zipf during part of this investigation.

SUMMARY

1. The relationship between growth inhibition of the mesocotyl of *Avena sativa* and the intensity of the radiant energy causing it has been determined for a number of relatively narrow wave-length bands in the visible spectrum. At low intensities the inhibition is proportional to the logarithm of the intensity.

2. From these data a provisional action spectrum of mesocotyl inhibition has been plotted. This shows a single peak at approximately 6600 A. and an indicated secondary maximum in the neighborhood of 6200 A.

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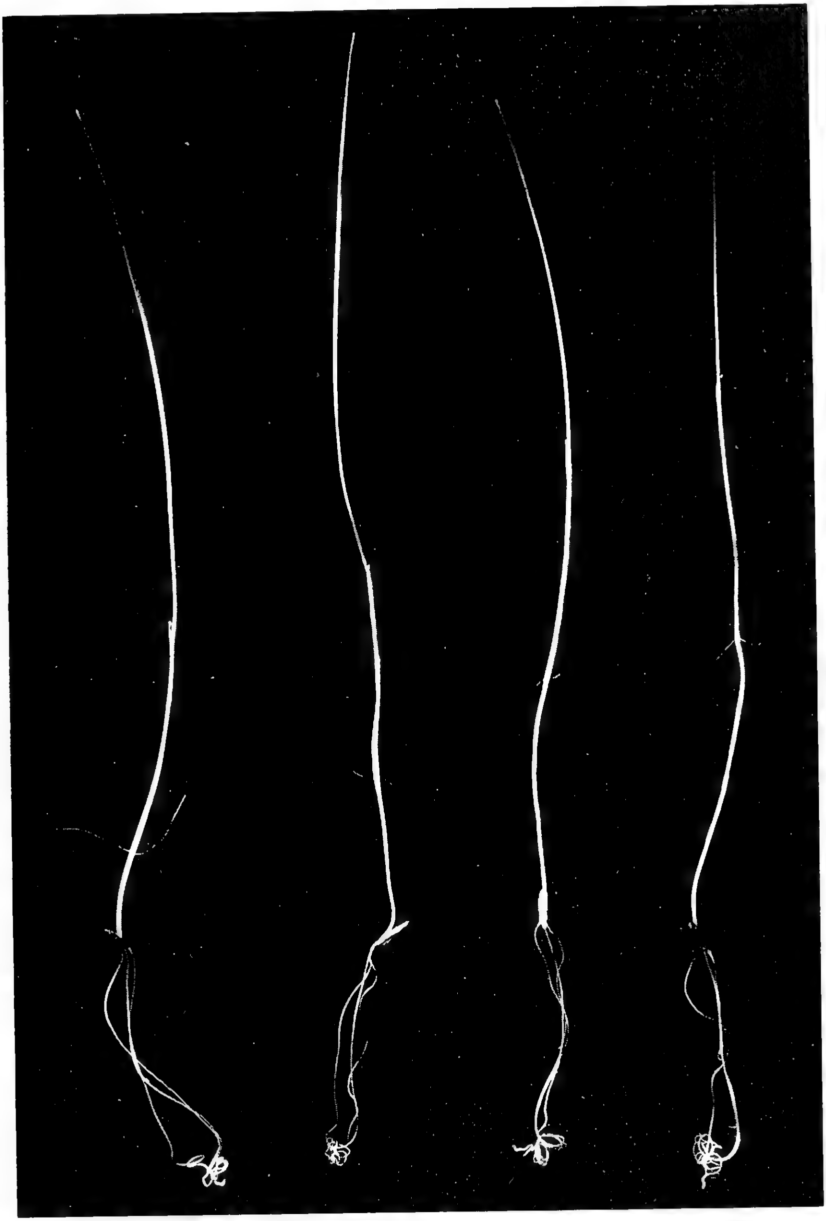

REPRESENTATIVES OF FOUR SERIES OF SEEDLINGS OF AVENA SATIVA GROWN UNDER VARIOUS LIGHT INTENSITIES

The apical limit of the mesocotyl is indicated by the adventitious roots at the coleoptilar node.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 101, NUMBER 18
(End of Volume)

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(With One Plate)

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The occurrence of *Blepharipoda* on the east coast of South America, first reported by Carlos Berg (1900, p. 225), has long been of interest (Porter, 1911, p. 17; 1916, p. 279). Heretofore, specimens from both the Atlantic and Pacific coasts have always been identified with Randall's species, *B. occidentalis* (1839, p. 131, pl. 6), the type of the genus, which ranges along the west coast of North America from San Francisco, Calif., to San Quentin and [Santa] Rosalia Bays, Lower California. San Diego, Calif., is its type locality.

In the course of determining three Blepharipodas on loan from the Argentine National Museum[1] through the kindness of the Director, Dr. Martin Doello Jurado, it was discovered that they represented an undescribed species. This species I take great pleasure in naming in honor of Dr. Doello.

As a result of this discovery, I naturally wanted to see Philippi's *B. spinimana* (1857, p. 129, pl. 8) from the coast of Chile, which at least as far back as the turn of the century (Ortmann, 1896, p. 222) had been relegated to the status of a synonym of *B. occidentalis.* Our absolute lack of comparative material was most generously remedied by Dr. Carlos E. Porter, from whom we received a dried female of good size collected at Antofagasta by Prof. José Herrera. This specimen made it possible to validate Philippi's species. I am also indebted to Dr. Porter for certain rare items of his own writings dealing with *Blepharipoda.* In two of these (1915, p. 78; 1916, p. 280) very complete bibliographic references are given, along with some very helpful personally entered annotations, as well as a copy of one of his very recent publications in which the occurrence of the Antofagasta *Blepharipoda* received from Dr. Porter was first reported upon (1940, p. 311).

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[1] Museo Argentino de Ciencias Naturales, Buenos Aires.

All Chilean records for *Blepharipoda* should now be referred to *B. spinimana* (Philippi), and, as far as we know, those from the Argentine to *B. doelloi* described below. Besides these two and the genotype, only one other real *Blepharipoda* seems to have appeared in literature, *B. spinosa*[2] (*Albunhippa spinosa* Milne Edwards and Lucas, 1841, p. 477, pl. 28, figs. 1-13). This species, if valid, remains yet to be rediscovered. As Miers (1878, p. 335) has already remarked, well over half a century ago, "The locality whence the specimen described by Milne Edwards and Lucas was obtained is not stated; and there is nothing in their description to distinguish it from either of the foregoing species. The hands are represented in the figure as devoid of spines, but are described as spinose. Dana [1850, p. 406] gives no particulars which would serve to characterize the specimens collected by the U. S. Exploring Expedition [at San Lorenzo, Peru]."

Two other "sand bugs," believed at the time of their description to have been Blepharipodas, are *B. japonica* Duruflé (1889, p. 93, one fig.) and *B. fauriana* Bouvier (1898a, p. 566; 1898b, p. 339, figs. 1-5). According to Balss (1914, p. 92) the second of these is a synonym of the first, and this in turn is more properly a representative of the genus *Lophomastix* defined 10 years earlier by Benedict (1904, p. 621).

BLEPHARIPODA DOELLOI, new species

Blepharipoda occidentalis Berg, Com. Mus. Nac. Buenos Aires, vol. 1, No. 7, p. 225, 1900 (specimen from Mar del Plata).—Porter, Bull. Mus. Hist. Nat. (Paris), vol. 17, No. 1, p. 17, 1911 (specimen from vicinity of Bahia Blanca); Rev. Chilena Hist. Nat., vol. 19, p. 78, fig., 1915 (specimens from Argentina); Physis (Buenos Aires), vol. 2, p. 279, fig., 1916 (specimens from Argentina).

Description.[3]—Because of the limited material at hand, nothing can be stated definitely regarding the maximum or even average size of our new species as compared with its congeners. The three specimens of *B. doelloi* are very much smaller than all the *B. occidentalis* I have seen except one small specimen lacking locality data which is about the same size as the average of our specimens of *B. doelloi.* What appears to be the largest specimen of *B. occidentalis* in the collections of the United States National Museum measures all of

[2] Misspelled *speciosa* in the key given by Bouvier (1898b, p. 342) in his "Observations nouvelles sur les Blepharopoda Randall (Albunhippa Edw.)."

[3] This description is largely a comparison of the new species with the well-known *B. occidentalis* Randall and the here reestablished *B. spinimana* of Philippi. It is believed that the distinguishing characters of the new species will be better presented in this manner.

57 mm. in median length of carapace, rostral projection included. The single available dried specimen of *B. spinimana* measures 27.5 mm. on the median line of the carapace, exclusive of the distal extremity of the rostral projection which is lacking.

As compared with *B. occidentalis,* the anterior portion of the carapace of *B. doelloi* before the cervical groove is very little roughened; the scabrosities [4] of the central area are confined largely to a narrow interval either side of the median ridge or carina; in *B. spinimana* a very similar condition obtains. In *B. occidentalis,* on the other hand, except for a small, more or less circular smooth area either side of the median line just behind the level of the dorsal spine, the anterior portion of the carapace is very generally and conspicuously roughened or scabrous. This character alone will at once distinguish *B. occidentalis* from the other species here discussed.

The rostral projection of *B. doelloi* is distinctly shorter than the lateral projections of the front which, though subacute, are elongate triangular; their inner, orbital margins are straight and very nearly longitudinal; the distance from the level of the posterior margins of the orbital sinuses to the level of the anterior extremities of the lateral projections of the front is considerably greater than half the distance from the tip of one lateral projection to the other, or, stated another way, very appreciably greater than the distance, at the same level, from the tip of either lateral projection to the median line of rostral projection extended. In *B. occidentalis* the rostral projection normally (and in almost every instance) reaches the level of the anterior extremities of the lateral projections, and often a little beyond; the lateral projections from their more acute, more spiniform tips backward are more broadly triangular than in *B. doelloi* and so have the inner margin oblique to the median line and not subparallel as in *B. doelloi;* measured as in *B. doelloi,* the lateral projections of the front are usually much less in length than half the distance between their tips (fall short of the distance from the tip of either lateral projection to the median line of rostral projection). Similar measurements cannot be satisfactorily made for our one specimen of *B. spinimana,* as the distal extremities of all three frontal projections are wanting; yet, if Philippi's figure noted above can be depended upon, the rostral projection extends scarcely more than half as far forward as the lateral projections of the front. As compared above, the orbital

[4] Strictly speaking, this apparent roughening of the surface of the carapace where it occurs in the several species of *Blepharipoda* consists of little short, transverse, or transversely arched impressions, most of which have their posterior margins pectinate and often hairy.

sinuses of *B. doelloi* are much narrower and deeper than the wider, shallower, and less triangular ones of *B. occidentalis.* Owing to the straight, longitudinal inner margin of the lateral projections of the front, the orbital sinuses of *B. doelloi* have an asymmetrical, sharply angled posterior margin, the apex of the angle lying close to the posterior end of the straight inner margin of each lateral projection; the posterior orbital margin of *B. occidentalis* is more or less broadly concave, at best only obtusely and, in any case, more or less symmetrically angled; in *B. spinimana* the posterior orbital margin is more sharply angled, as in *B. doelloi,* but, on the other hand, symmetrically so, the apex of the angle lying about midway between the major axis of either lateral and the median rostral projection.

The length of the long, slender first anterolateral spine of *B. spinimana* either side, measured (as a chord) from the level of the posterior margin (or apex) of the sinus between it and the side of the carapace, is much greater than half (three-fourths or more) of the distance between the apices of the lateral projections of the front. In *B. occidentalis,* the anterolateral spines are stouter and less than half as long as the distance between the apices of the lateral projections of the front. In *B. spinimana,* because the tips of the anterolateral spines are broken off, this character cannot be directly compared with the other two species.

In the genus *Blepharipoda* there is a fairly well marked groove running transversely inward from just before the antepenultimate spine of the lateral margin; behind this groove in turn is a similar but more profound one arising from just before the posteriormost of the lateral spines, and running obliquely inward and forward at roughly a 45° angle; this second oblique groove intersects, or if extended would intersect, the first-mentioned transverse groove. The hinder margin of these grooves, like that of the transverse frontal groove before the median carapacial spine and the posterior margins of the impressions on the surface of the carapace, is, in the known species, more or less pectinate and hairy.

From the point or locus where the two grooves intersect, or would intersect if sufficiently extended, what may be regarded as the continuation of the transverse groove takes on a different general direction in each of the three species of *Blepharipoda* here discussed.

In *B. doelloi* this apparent or actual continuation of the transverse groove turns forward at about a 45° angle and, in effect forms a continuation of the oblique groove. This character is another that definitely distinguishes our new species from both *B. occidentalis* and *B. spinimana.* In *B. occidentalis* the inner portion of the transverse groove beyond the point where the oblique groove would intersect it is practically a "straight" continuation of the transverse groove with, if anything, a slight downward or backward trend; while in *B. spinimana* the inner portion of the transverse groove is a little arched or curved (forwardly convex) so that it appears to be on the inwardly curved end of the oblique groove.

In general, the chelipeds of the three species of *Blepharipoda* compared are very similar and similarly armed, yet a close inspection of their spinous armature reveals certain significant and rather constant details regarding the spines, their placement, and number. Throughout, the spines in *B. spinimana* are longer, stronger and relatively more conspicuously prominent, as its specific name would indicate. The dactyl of the chela in this species is no more than a strong, flattened spine with straight, not curved, margins, converging to form a very acute, slender (stilettolike) tip, its outer or upper margin is armed with two prominent, long, slender, and fairly straight spines; the anterior of the two spines is about two-thirds the length of the dorsal margin of the dactyl distal to its base, at first glance the spine in length appears almost subequal to the distal portion of the dactyl; the second, more proximal, of the two spines is very little less strong than the distal one; behind it there is a low, conical, subacute and not very conspicuous tubercle, a little better developed and more of a little cone on the right hand than on the photographed left. The prehensile margin of the fixed finger, or pollex, is armed with five spines, of which the distalmost is very strong and large; to all appearances it overshadows in size the distal spinelike portion of the pollex lying beyond it, although it actually is no longer and a little more slender (more circular in cross section) and not so compressed; the penultimate of the five spines is very little shorter or very little more slender than the ultimate one; but the next three are very much smaller and diminish rapidly in size, the most proximal one being very little more than a tiny pointed denticle or small spinule, well-nigh lost to sight in the thick fringe of hair with which the margin of the pollex is furbished. The upper margin of the carpus behind its conspicuously spinous anterior dorsal angle is armed with one larger spine about as large as the largest on the prehensile margin of the dactyl, followed by a very small spine; between the two spines there may be, as in the left but not the right hand, two tiny spinous, pricklelike denticles.

In *B. doelloi* the upper margin of the dactyl of the chela is likewise armed with two slender spines, but these are forwardly curved and relatively much less strong and prominent than the corresponding spines in *B. spinimana;* the dactyl is gently curved or bowed, and slightly hooked toward the tip; the anterior of its two (in each of the three specimens at hand) dorsal spines is only about one-third the length of the dorsal margin of the dactyl extending in front of its base. The more proximal of the two spines is between three-fourths and four-fifths the length of the distal one; behind it there is no tubercle or denticle comparable to the one present in *B. spinimana.* The prehensile margin of the fixed finger or pollex is armed with three sharp, more or less subequal conical spines (antepenultimate usually a little smaller than ultimate), followed by a small, inconspicuous denticlelike fourth spine and two little equidistant projections, or scarcely to be noticed sinuosities, of the margin; perhaps they are suggestive indications of a normally undeveloped fifth and sixth denticle. The distalmost of the series of spines on the fixed finger is about one-fourth the length of the prehensile margin of the pollex in advance of the base of the spine. The upper margin of the carpus is armed at about its anterior third with a single spine about the size of, or slightly larger than, the spine arming the anterodorsal angle of the carpus; it is also about the size of the more distal and larger of the two spines arming the dorsal margin of the dactyl; behind this spine the upper margin of the carpus is smooth and unarmed; on its inner surface the carpus is armed with a strong double or bifid (to the base) spine in the case of the left cheliped only; in the right carpus there is but a single spine in this position, as in *B. spinimana* and *B. occidentalis.*

In *B. occidentalis* the dactyl is appreciably curved or bowed from base to tip; its upper margin is armed with three or four spines, rarely only two, and occasionally with five, the two distalmost spines are of good size, but, as in *B. doelloi,* relatively much less prominent than in *B. spinimana,* the most anterior, or distal spine of the series is about two-fifths or less of the length of the dorsal margin of the dactyl extending in front of its base; the penultimate spine is usually nearly as large as the ultimate one, and sometimes, as in the figured left hand of this species, even larger. The prehensile margin of the pollex seems usually to be armed with five spines of which the distalmost is much the larger and about the size of the ultimate one of the series arming the dorsal margin of the dactyl, the succeeding spines diminished rapidly and regularly in size to the most proximal one which is small but stout, and more of a conical tubercle than a spine. Behind its spinous anterodorsal angle the upper margin of the carpus is armed with three or four spines (in the series before me there is just one specimen with two spines on one carpus only) situated in about the penultimate fourth of the dorsal margin of the joint.

The dorsal margins of the carpi of the first and second pair of legs following the cheliped (second and third pair of peraeopods) are denticulated or spined; the spines are much more numerous, more closely set, sharper, and more spiniform and take in more of the margin in *B. occidentalis* than in *B. doelloi;* in *B. spinimana* those on the carpi of the second peraeopods, at least, appear stouter and more conical-tuberculiform than spiniform, as compared with the other two species. There are appreciable differences in the dactylar joints of each of the peraeopods following the chelipeds, most readily observed in the case of the dactyls of the second pair of peraeopods. In the first place, a straight edge laid across the more or less straight basal, proximal portion of the anterior margin barely intersects the tip of the fingerlike distal portion of the dactyl in *B. occidentalis,* as is the case also in *B. spinimana;* in *B. doelloi,* however, such a straight edge laid along the anterior margin of the proximal basal portion of the dactyl cuts off a third to a half of the fingerlike distal process of the dactyl.

In the second place, the more or less straight basal, proximal portion of the dactyl has the mid portion of its margin shallowly excavate both in *B. occidentalis* and *spinimana,* while in *B. doelloi,* where the margin seems relatively shorter, it is in general outline gently or slightly convex, though in its mid portion, at least, it may be rather straight.

In the third place, the sinus between the distal fingerlike process and the basal portion of the dactyl is differently shaped in each of the Blepharipodas: in *B. occidentalis* it is relatively narrow, and noticeably obliquely undercuts the distal end of the basal portion; in *B. spinimana* the proximal margin of this sinus would form more or less of a right angle to a straight edge laid across the anterior (or dorsal) margin of the basal portion of the dactyl, or even very slightly or almost imperceptibly obliquely undercuts the basal portion; while, on the other hand, in *B. doelloi* the proximal margin of the sinus forms an angle very slightly more than a right angle.

There are also comparable differences in the shape, marginal outline, and relative proportions of the dactylar joints of the last two pairs of peraeopods, particularly in those of the fourth pair. Using the more or less straight anterior or upper margin of the basal portion of the dactyl just distal to the articulation of this joint with the carpus as a base line, the perpendicular height or depth of the dactyl of *B. occidentalis,* taken at the distal end of this base line, is subequal to, or very little greater than, the distance that the tip of the dactyl extends beyond the perpendicular on which the height of the dactyl is measured; while in *B. spinimana* and *B. doelloi* it is noticeably greater, in the former about one-fifth of the perpendicular height of the dactyl greater, and in the latter a third greater (cf. fig. 8).

Examining a *Blepharipoda* from below, one will observe at least some armature in the shape of a spine or conical tubercle on the anterior face of the coxopodites of one or more of the peraeopods following the chelipeds. In the male of our new species the coxa of the second peraeopod is furnished with two such spines each on the second and third, and one on the fourth, while the holotype female is correspondingly armed with two, one, and one spines. The male of *B. occidentalis* has two spines on the coxa of the second peraeopod, one on the third, and only a rather small conical tubercle on the fourth; the female has a single spine on the coxa of the second peraeopod and none on the third or fourth; in these two peraeopods a very small, or at most a tiny beadlike indication may be noted on close inspection in some specimens in the position where a spine might be expected and does occur in the other species. Of *B. spinimana* we have but the one female, the coxae of second peraeopods of which are spined as in the female of *B. occidentalis,* except that no beadlike indications appear to occur on the third and fourth peraeopods.

The telson of neither the male nor female of *B. doelloi* seems to show anything of the posterior median emargination so plainly evident in *B. occidentalis* and *B. spinimana;* instead, the margin of the telson of *B. doelloi* is continuous and appears to go evenly around the posterior end from one side of the telson to the other. I am not unmindful of the fact that Randall, in his original figure of *B. occidentalis* (1839, pl. 6), and apparently Philippi also, for his *"Abrote [Blepharipoda] spinimana"* (1857, pl. 8), depicted the telson of their respective species as posteriorly pointed or acuminate, a condition reminiscent of some of the Albuneas, and more remotely of the Hippas in general. I have personally yet to encounter a similarly pointed telson in any *Blepharipoda.* Of *B. occidentalis,* in particular, I have examined a considerable number of individuals of both sexes.

Material examined and figured.[5]—

Blepharipoda doelloi:

Female holotype, 22 mm.

Mar del Plata, Argentina, February 1924, coll. "Atair," Leloir and Franceschi; one of three specimens collected, M.A.C.N. No. 14303.

Female paratype, 19 mm.

Quequen, coll. G. Haedo, M.A.C.N. No. 13946.

Male allotype, 15 mm.

Quequen, coll. G. Haedo (hijo), M.A.C.N. No. 14189.

[5] The measurements given represent the median length of the carapace, inclusive of the rostral projection.

Blepharipoda occidentalis:

Female, 36.5 mm.

Male, 29.5 mm.

Both from Long Beach, Calif., coll. H. N. Lowe [1910], U.S.N.M. No. 79389.

Of this species a considerable series ranging from San Francisco, Calif., to Santa Rosalia Bay, Lower California, Mexico, has also been examined.

Blepharipoda spinimana:

Female neotype, 27.5 mm.

Province of Antofagasta, Chile, coll. Dr. José Herrera, U.S.N.M. No. 79390.

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DESCRIPTION OF PLATE

Plate 1

Figs. 1-3. *Blepharipoda doelloi* new species.

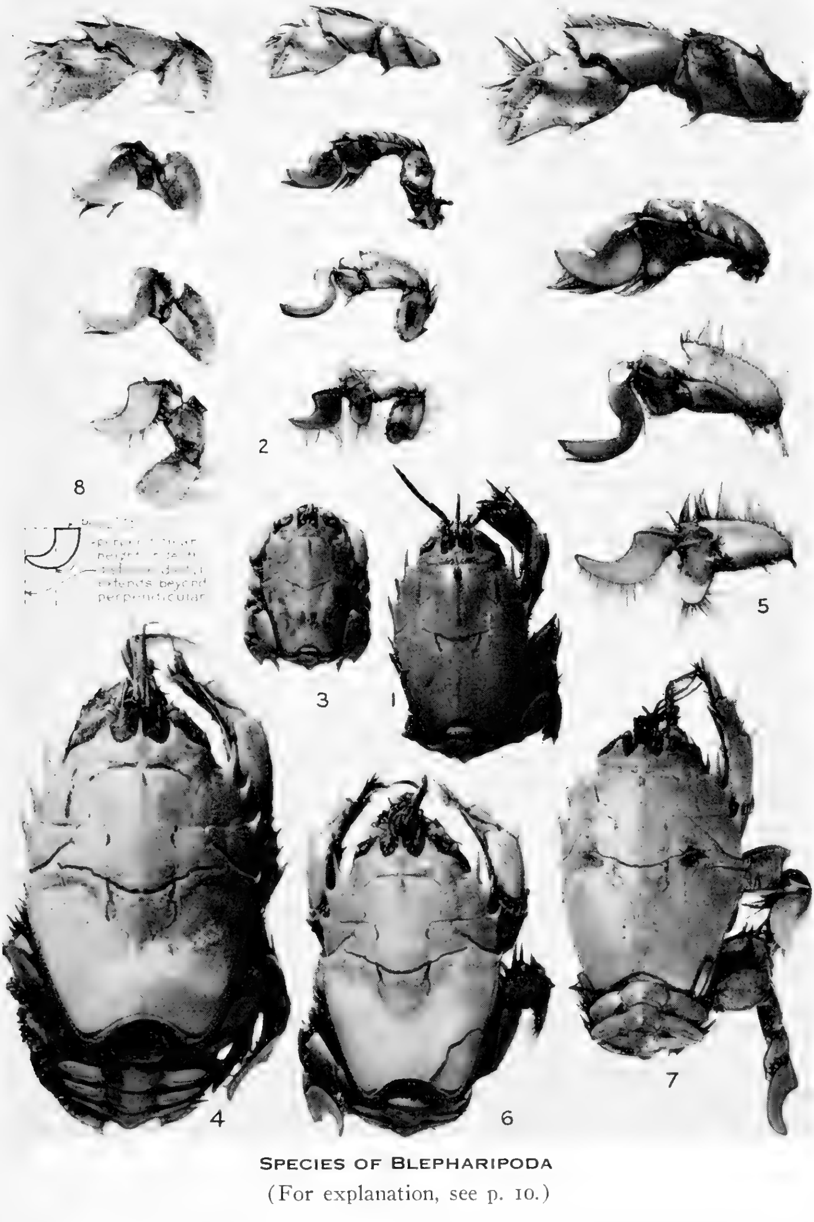
1. Dorsal view of female holotype from Mar del Plata, Argentina; median length of carapace, inclusive of rostral projection, 22 mm.
2. First four peraeopods of left side of same.
3. Dorsal view male allotype from Quenquen, Argentina; median length of carapace, inclusive of rostral projection, 15 mm.

Figs. 4-6. *Blepharipoda occidentalis* Randall.

4. Dorsal view of female from Long Beach, Calif.; median length of carapace, inclusive of rostral projection, 36.5 mm.
5. First four peraeopods of left side of same.
6. Dorsal view of male from Long Beach, Calif.; median length of carapace, inclusive of rostral projection, 29.5 mm.

Figs. 7, 8. *Blepharipoda spinimana* (Philippi).

7. Dorsal view of female from Province of Antofagasta, Chile; median length of carapace, inclusive of broken rostral projection, 27.5 mm.
8. First four peraeopods of left side of same, with diagram indicating method of taking measurements of dactyl of fourth peraeopod discussed on p. 7.



Species of Blepharipoda

(For explanation, see p. 10.)