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Scientific Results of the Katmai Expeditions of the National Geographic Society.

I. THE RECOVERY OF VEGETATION AT KODIAK.*

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PREFATORY NOTE.

When its magnitude is fully understood by the scientific world, the eruption of Katmai is certain to rank with that of Krakatoa as a unique exhibition of the forces of vulcanism. To the National Geographic Society alone belongs the credit of having made known to the world this tremendous eruption. As soon as the news came that there had been a great volcanic explosion in Alaska, the society dispatched Dr. Geo. C. Martin to the scene. His report published in the National Geographic Magazine for February, 1913, remains the only detailed record of the events of the eruption. This first study was followed up by three other expeditions under the direction of the writer, whose results have been summarized in the National Geographic Magazine for January, 1917 and February, 1918.

The purpose of the society in sending these expeditions was, however, quite as much to undertake detailed study of the numerous scientific problems raised by the eruption as to furnish its members with authentic accounts of one of the greatest volcanic disturbances in history. Hand in hand with exploration of interest to all of the 750,000 members of the society, has always gone intensive study of numerous scientific problems which would appeal to a more restricted audience. The Board of Managers of the society has from the first recognized that the expeditions would fail in their purpose if they brought back nothing beyond material for articles suitable for a magazine of general interest to all intelligent people. These articles are, to be sure, as accurate and as truly contributions to knowledge as the most recondite memoir. But it is recognized that they must be brief epitomes in which the detailed data essential to the progress of science must be cut out on account of the limitations of space.

The expeditions of 1915-1916 owed their inception to the foresight of Mr. Frederick V. Coville, of the Board of Managers, who first recognized the unique opportunity presented by the revegetation of the ash for the solution of many problems of great importance to agriculture connected with the transformation of the raw mineral ash into a humous soil. It was primarily for the study of these problems that the project was undertaken, for no one at that time suspected the existence of the volcanic wonders which were to prove of wider general interest than the specific objective of the expeditions.

Although it has been the intention of the society to provide for the comprehensive study of all the scientific problems growing out of the eruptions, the members of the expeditions have been able to realize this ideal only in part. The scientific problems presented in this remarkable district are so manifold that it has always been necessary to forego the study of many important aspects of the eruption. The eruption was, moreover, so vast a cataclysm that its comprehension passes the power of the human mind. The members of the expeditions have always felt that the results attained were to be measured only by their own limitations of vision and of strength for following up the opportunities that lay around them on every hand.

Good progress has, however, been made along a number of major lines, including the botany of the region; its revegetation so far as that has progressed; the geology of the volcanic district; studies of the volcanic phenomena in some detail; the chemical condition of the ash plains in relation to their colonization by plants; chemical and thermometric examinations of the volcanic emanations in co-operation with the Geophysical Laboratory of the Carnegie Institution; the zoology of the district, the insects especially having received attention thus far; while beginnings have been made in the study of the soil bacteriology and mycology of the devastated areas.

For various reasons the publication of the papers embodying the results of these investigations has been somewhat delayed, but it is now proposed to issue, as rapidly as possible, a series of contributions of which this is the first, making known the results which have been obtained. Inasmuch as the National Geographic Society has no organ of its own suitable for such papers, the Ohio Journal of Science has undertaken the publication under an agreement whereby the Geographic Society assumes the major share of the expense.

The eruption of Katmai and its effects on vegetation have been discussed in previous papers.[1-2-3] The present paper is presented as a more detailed record than could be given in the general account of the remarkable recovery shown by the plants buried under the ashfall at a great distance from the vent.

"GREEN KODIAK" TRANSFORMED TO A DESERT.

It will be recalled that although a hundred miles from the Volcano, Kodiak was covered about a foot deep by the fall of ash, which here has the character of fine sand. The effect of this blanket of ash, coming as it did on June 6, just as the plants were putting forth their spring growth, was to strike down all herbaceous growth, giving "Green Kodiak" the appearance of a pine barren, devoid of vegetation except for the trees and bushes which stuck through the ash uninjured. To everyone who visited Kodiak during the first two seasons after the eruption, the damage done to vegetation seemed irreparable.

It was during this period that I first saw Kodiak in June, 1913, almost exactly a year after the eruption. It was indeed a bleak and desolate prospect. Outside the forest the country had the appearance of a desert, whose gray-brown slopes were relieved only here and there by spots of green where some alder or willow stuck through the ashy blanket (see page 4), or on some steep slope where the ash had been washed off. Lupines, fireweeds, and other strong-stemmed perennials had, to be sure, come up through the ash here and there, but they were not abundant enough to have much effect on the landscape. Within the forest the prospect was less desolate because the spruces stood up out of the ash in something like their original condition, but the undergrowth beneath them was gone and

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[1] Rigg, G. B. The Effects of the Katmai Eruption on Marine Vegetation. Science 40 : 509–513. 1914.

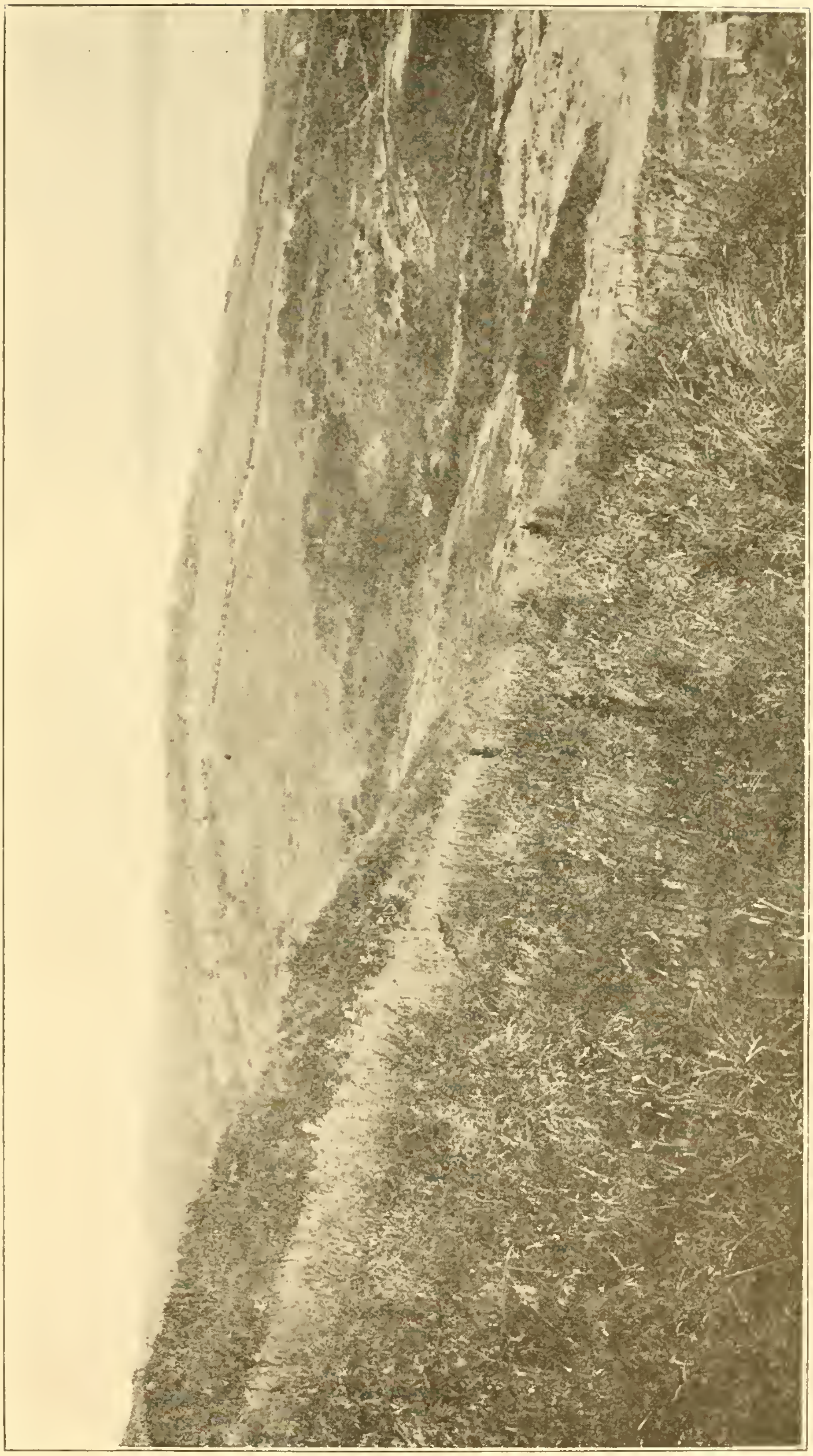
[2] Griggs, Robert F. The Effect of the Eruption of Katmai on Land Vegetation. Bull. Am. Geogr. Soc. 47: 193–203; Figs. 1–10. 1915.

[3] ——, The Eruption of Katmai. Nature 101: 497. 22 Aug., 1918.

Photograph by M. D. Snodgrass

ASH COVERED LANDSCAPE NEAR KODIAK.

At the end of the first growing season after the eruption. October 20, 1912.



Photograph by B. B. Fulton

THE SAME PLACE THREE YEARS LATER.

Rank grasses have everywhere covered the hillsides coming up from old roots. The only bare ash yet remaining is in the old swamp at the right.

their branches were still heavily laden with ash, bending them down against the ground (see page 48).

The officials of the Experiment Station and of the Kodiak Baptist Orphanage were attempting to grow a crop of oats to provide ensilage enough to keep their cattle alive over the winter. We felt it our duty to encourage them in this effort, but in reality the prospect seemed very gloomy to us. Well do I remember debating with one of the citizens whether the country would ever come back to its original condition. He, with the vividness of his memory of things as they had been before the eruption, was pessimistic, but I, with the knowledge that the ash would probably be beneficial after it was incorporated with the soil, reassured him with the prediction that in ten years vegetation would begin to come back in some abundance.

THE MARVELOUS RECOVERY OF VEGETATION.

But during the second and third years the old roots sent up new growth through the ash layer in such profusion as to completely upset even the most optimistic of predictions. When I landed in June 1915, despite the reports I had received, I could not believe my eyes. It was not the same Kodiak that I had left two years before. The mountains were everywhere green with their original verdure. The character of the change is indicated by the pictures on pages 4, 5 and 7 better than it could be by any description. Where before had been barren ash was now rich grass as high as one's head. Everyone agrees that the eruption was "the best thing that ever happened to Kodiak." In the words of our hotel keeper, "Never was any such grass before, so high or so early. No one ever believed that the country could grow so many berries, nor so large, before the ash."

I had come to Kodiak to study the revegetation, but I found my problem vanished in an accomplished fact. The revegetation which I had hoped to study at Kodiak had given place to a remarkable recovery of the antecedent plants, transferring the problem of revegetation proper to the more deeply buried country near the Volcano.

GRASS COME UP THROUGH THE ASH. *Photograph by D. B. Church*

In some places this grass, the native blue top, *Calamagrostis langsdorfii*, penetrated twenty inches of ash. The connection of the present tops with old roots, hold-overs from before the eruption, is everywhere manifest.

COMPARISONS WITH REVEGETATION IN OTHER VOLCANIC DISTRICTS.

But, although the country around Kodiak presents only a subordinate aspect of the problem of revegetation, it is, as may be seen below, more similar to most of the other volcanic districts whose revegetation has been studied, than the country nearer the volcano. It seems appropriate, therefore, to digress at this point for a comparison of the Katmai district with other volcanic regions.

There is a very natural tendency on the part of many to group the revegetation of all volcanic terrains under a single generalization. Considering how remote volcanic phenomena are from the experience of most botanists, this is quite excusable. But when one's attention is called to the fact that volcanic ejecta not only vary in physical condition all the way from compact glassy rock to fine sand, but also have all the varieties of chemical composition shown by igneous rocks from basic to acid, he sees at once that the establishment of plant life on different volcanic terrains may be as diverse as on soils derived from different varieties of sedimentary rocks. The problems encountered by Forbes[4] and MacCaughey,[5] for example, in studying plant invasion on Hawaian lava flows have little in common with those that confront us in the Katmai district.

Moreover, as our knowledge of the phenomena of the eruption increases, and the affected country is better explored, it becomes more and more evident that the eruption of Katmai stands in a class by itself, offering opportunities for the study of revegetation quite without parallel since the development of modern botany, before which, of course, no such studies could have been made.

KRAKATOA.

The eruption of Krakatoa, for example, will occur to botanists and geologists alike as the greatest of volcanic explosions. Yet the total area on which the studies of revegetation were made, the island of Krakatoa, was only about five square miles in extent—so small that it could almost be dropped

[4] Forbes, C. N. Prelim. Obs. Concerning the Plant Invasion on Some of the Lava Flows of Mauna Loa, Hawaii, Bishop Mus. Honolulu. Occ. Pap. 5: 15–23. 1912

[5] MacCaughey, Vaughan. Vegetation of Hawaiian Lava Flows. Bot. Gaz. 64: 386–420. 1917.

bodily into the crater of Katmai. In the present case, the area covered by deep deposits, through which the roots of plants can not reach the original soil, is more than a hundred times as large.

Unfortunately, moreover, the study of Krakatoa was of a very fragmentary nature. It was three years after the eruption before the island was visited at all. Revegetation had already begun on an extensive scale[6]. This first plant life consisted of blue-green algæ and ferns, but several species of seed plants were already well established. After this first brief visit no other observations are recorded for eleven years, until 1897 when it was visited by Penzig[7]. After this visit, a similar period elapsed before another visit, that of Ernst[8] and Campbell[9]. Although Ernst has worked up the data gathered, in masterly fashion, it should be remembered that his opportunity for field examination was very brief, consisting of only a few hours, during which time it was not possible so much as to reach the summit of the island, much less to explore it carefully.

These workers, moreover, paid little attention to the problem which most concerns us, namely, the means of preparation of the raw inorganic soil for the life of higher plants, but studied especially the means of dispersal by which the plants reached the new land, making the observations the basis of a study in plant distribution for which Krakatoa, by virtue of its insular position, offered a unique opportunity not duplicated at Katmai.

Since these papers are well known to most botanists, there is no occasion to abstract them at length here. Probably the most significant of the results brought out are the following: (1). The pioneer vegetation consisted not of flowering plants, but of Blue-green algæ (Cyanophyceæ), which were followed by ferns and then by flowering plants. (2). The first flowering plants were species whose seed was either distributed by the wind or by ocean currents, invasion progressing largely from the strand. (3). It was believed that the nitrogen compounds necessary for the growth of the luxuriant vegetation were

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[6] Treub, M. Notice sui la nouvelle Flore de Krakatau. Ann. Jard. Bot. Buitenzorg 7: 213–223. 1888.

[7] Penzig, O. Die Fortschnitte der Flora des Krakatau. Ibid 21 : 92–113. 1902.

[8] Ernst, A. The New Flora of the Volcanic Island of Krakatau. Translated by A. C. Seward. Camb. Univ. Press. 1908.

[9] Campbell, D. H. The New Flora of Krakatau. Am. Nat. 43: 449–460. 1909.

derived in part from the activity of nitrogen fixing soil bacteria, and in part from compounds formed in the atmosphere by electrical storms. This suggested solution of the nitrogen question is of great interest in connection with our problem.

TAAL.

The return of vegetation to the slopes of Taal volcano in the Philippines after the destructive eruption of January, 1911, has been studied first by Gates[10] and later by Brown, Merrill and Yates[11]. Although it entailed the destruction of many hundreds of human beings, this eruption was, by comparison with that with which we are dealing, a minor affair. The depth of the ejecta on the slopes of the volcano is stated by Worcester[12] to have been only 8-12 inches, while at the foot of Katmai, eight miles from the crater, the ashfall was eleven feet on the level. It is clear, therefore, that the return of vegetation to Taal is more nearly comparable to the recovery at Kodiak than to the revegetation of the mainland areas in the vicinity of the volcano.

Gates reported that "more than 99% of the new vegetation are seedlings," but the sterilization even of the volcano island was by no means complete, "for in April, 1914, bananas were fairly abundant and indicated quite well the positions of many of the former houses" while several species of bamboo, which are likewise exclusively culture plants unable to spread without human assistance, were prominent. Since only three clumps of bananas and none of the bamboo were present in October, 1913, the indications are that these tropical plants have a capacity for undergoing long dormant periods beneath the ground, analogous to that found in the Katmai district (see page 32).

The investigations of Brown, Merrill and Yates suggest that a larger proportion of the native plants likewise, may have survived than was supposed by Gates. The most important species in the new vegetation is a grass *Saccharum spontaneum*, which "has characteristic deep seated rhizomes." From observations of the rate of growth, they believe "that the dense

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[10] Gates, Frank C. The Pioneer Vegetation of Taal Volcano. Philip. Jour. Sci. 9: Sec. C. 391–434. Pl. 3–10. 1914.

[11] Brown, W. H.; Merrill, Elmer D.; and Yates, Harry S. The Revegetation of Volcano Island. Philip. Jour. Sci. 12: Sec. C. 177–248. Pl. 4–16. 1917.

[12] Worcester, Dean C. Taal Volcano and Its Recent Destructive Eruption. Nat. Georgaphic Mag. 23: 313–367. 1912. Citation on p. 350.

stands of grass that Gates found in 1913 and 1914 would have required more than three years to develop from seed." Of the trees also, the two most abundant species, *Acacia farnesiana* and *Ficus indica*, were probably both hold-overs. *Acacia farnesiana* has a notable ability "to regenerate after the aerial portions of the plant have been killed by fire," and specimens of *Ficus indica* were "observed that had apparently sprouted from old stumps."

The return of plant life at Taal followed very much the same course as at Kodiak. There was the same initial period, when it appeared that nearly all of the old plants had perished. Writers, describing the eruption, state that its effect on plants as well as animals is "better described as annihilation than as destruction" for "not a blade of grass escaped." But then there came a sudden revival from the old roots when it seemed that complete recovery would be a matter of only a few years, and then a second pause, as the process slowed up, while the plants slowly spread against the adverse conditions.

The ejecta from Taal differ markedly from the ash of Katmai in that, instead of being composed almost entirely of insoluble materials, they contain "nearly 5% of material readily soluble in water, including 0.3% sulphuric anhydride (SO_3) and 0.74% chlorine. This would indicate that such ash would not form soil favorable for plants until after the water-soluble material had been leached out to a very considerable extent." This introduces a retarding factor into the problem of revegetation quite different from anything encountered at Kodiak, for the ash of Katmai has very little water-soluble material.*

THE SOUFRIERE OF ST. VINCENT.

St. Vincent likewise has made a notable recovery since the eruption of 1902, as recorded by Sands[13], whose report has great interest in connection with the problem before us.

The depth of the covering of ejecta varied from 50 to 80 feet thick in some of the valleys, down to a few inches on steep slopes. On fairly level land, it was 1 to 5 feet. "Already quite a dense growth of shrubs, climbers, grasses and other

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* Data on the salt content of the ash are given in a forthcoming paper by J. W. Shipley, Chemist of the expeditions.

[13] Sands, W. N. An Account of the Return of Vegetation and the Revival of Agriculture in the Area Devastated by the Soufriere of St. Vincent in 1902–3. West Indian Bull. 12: 22–33. 1912.

plants has been formed. It is very evident that the greater part of this vegetation has become established from roots and seeds whose vitality was not destroyed by the eruptions. There are no trees; only a few charred trunks remain." They will, however, soon appear for seedlings are already starting. The commonest plants in the new vegetation "are the Roseau grass, Heliconia, Bamboo grass, *Impomœa umbellata* and *I. cathartica*, silver fern, Verbena, *Vitis sicyoides*, and hurricane grass; also several melastomaceous and rubiaceous bushes." Around the sites of former negro gardens are found sugar-cane, banana, and plantain. This type of vegetation continues with little change to an altitude of about 1,000 feet. "At 1,400 feet, plants are scantily distributed and the growth is poor." At 2,000 feet, silver ferns and mosses only are seen. 'From this altitude to the lower lip of the crater, approximately 2,800 feet, only algæ, mosses, and lichens are able to exist at present.' 'Around the edge of the crater, and inside for a short distance down, only two mosses, (*Pogonatum tenue* and *Philonatus tenella*), a lichen which grows in distinct circular patches (Stereocaulon sp.), and algæ, are found.' "

On the leeward side cultivation in the devastated area has been attempted only at one estate. Here, by a system of deep tillage and by utilizing large quantities of the pigeon pea and native weeds as green dressings, fair crops have been produced. These lands were covered with about 12 inches of ash, but this had been partly converted into soil by the large growth of native plants of the previous three or four years. "It still requires, however, very heavy applications of manure and organic matter to make it capable of producing average crops." But on the windward side a considerable portion of the broad plain is under cultivation in sugar-cane, cotton, arrowroot, pigeon peas and other crops. In this section scarcely anything remains to indicate that the whole district was a waste of ashes and cinders less than ten years ago.

In order to test the effect of the ash on plants, experimental plots of sugar-cane, arrowroot, sweet potatoes and ground nuts were started in the ash alone and in mixtures of ash and soil. These showed plainly "that the ash in itself could not support plant life—not a single crop could be successfully grown in it—but no sooner was a certain proportion of old soil mixed with it, or the plants were placed in the old soil, than crops, in some cases above the average of those produced before the eruptions, were obtained without the addition of manure; but only for one, and sometimes two years. That this temporary increase in fertility was not entirely due to deep cultivation is evident by the fact that only the upper 3 or 4 inches of the old soil were touched in the process, and that it is now necessary to manure heavily to obtain average crops." The cause of this temporary increase in fertility is believed to be due, not to "any available food materials in the ash or to any improvement in the physical condition of the soil," but to the effect of the partial sterilization of the soil by the heat of the ejecta, which increases the quantity of available nitrogen compounds because of the increase of bacteria consequent upon the destruction, by the heat, of the larger organisms that prey upon them, as has been found to be the case by Russel and Hutchinson at Rothamsted.

This explanation of the temporary increase of fertility by the ejecta is very interesting as, perhaps, in a measure accounting for the widespread idea that volcanic ash has value as a fertilizer. Although the ash from Katmai was not hot as it fell, there was some suggestion at Kodiak and elsewhere of a similar stimulating effect of the ash fall.

TARAWERA.

Among the notable eruptions of the last fifty years was that of Tarawera in 1888. This has been discussed recently in an excellent paper by Aston.[14] The following quotations will serve to summarize his conclusions:

"Occasionally, where the water-supply is favorable, lichens and moss may perform their usual function of transforming the barren rock into fertile soil, but the Raoulia must be accounted the great humus maker of this mountain. As it languishes in vigor, owing to age, from it grow other plants, the chief woody ones being Coriaria and Leptospernum, and sometimes Pittosporum, but also herbaceous plants such as Trifolium and *Rumex acetosella*. Four stages may thus be predicted for the repeopling of the plant-covering of this open area (excluding the ravines, which are able to jump the first

[14] Aston, B. C. The Vegetation of the Tarawera Mountains, New Zealand. Trans. N. Z. Inst. 48: 304–314. 1916. The same paper is published with minor changes in the text and somewhat different illustrations in the Journal of Ecology. 4: 18–26. 1917.

and possibly the second stages): first, the patch plants; secondly, the Coriaria; thirdly, the Aristotelia, with possibly Fuchsia and Melicytus; fourthly, forest.

"If the above list of the plants collected be analyzed, it will be seen that of ninety-one species observed on the isolated northwestern face, twenty-four (or 26 per cent.) may be called bird-distributed, fifty-three (or 58 per cent.) wind-distributed, and only fourteen (or 15 per cent) are difficult to account for."

THE GREAT PUMICE AREA OF NEW ZEALAND.

Another region, whose revegetation must have been more similar to the Katmai district than any of those yet mentioned, is an extensive area in New Zealand which was covered with a heavy deposit of ash and pumice by some prehistoric eruption. Revegetation has already occurred over this country, which has largely grown up to bushland or even to forest. A study of this area should throw much light on the processes by which the raw mineral ash is converted into soil. Such a study is not yet available, but the difficulties encountered by the colonists in attempting to utilize these lands for grazing throw a very interesting side light on the problem.

Although the forage plants grown on these pumice soils are normal, so far as reported, they are so seriously deficient as stock feed that cattle and sheep which are pastured on them shortly sicken and die of a curious malady locally known as "bush sickness." I am informed that horses may live for twenty years in perfect health on pastures which are fatal to cattle or sheep in the course of a few months. Sheep are more susceptible to "bush sickness" than cattle, and young animals more so than old. There is thus much borderland country where lambs cannot be raised to maturity, in which cattle suffer but little. The researches of Aston and his associates[15] indicate that the trouble is due to a deficiency of available iron in the forage, and considerable progress has been made toward alleviating the condition by applying some iron compound such as the sulphate to the soil. The investigation which is still in progress bids fair to throw much light on the general problem of revegetation of volcanic terrains.

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[15] Aston, B. C. The Chemistry of Bush Sickness. Jour. N. Z. Dept. Agriculture 5: 121–125. 1912. Also Ibid. 3: 394. 1911. 6: 616. 1913. And other articles there mentioned.

There is one point of dissimilarity between Katmai and all of the other eruptions cited, which is of great importance in the problem of revegetation. All of these volcanoes are located in tropical countries, while Katmai is on the edge of the subarctic zone. This of itself must compel the process of revegetation to take a widely different course. The differences introduced by the climatic factor promise, indeed, to become more and more interesting as time goes on, and it becomes possible to make better comparisons of the course of revegetation here and in warmer districts.

THE GREAT PREHISTORIC ERUPTION OF ALASKA.

Of all eruptions, the one which presents conditions most similar to that of Katmai is probably the Great Prehistoric Eruption which covered a vast area in the interior of Alaska and the Yukon territory with a thick blanket of ash and pumice. Capps[16] maps an area of one hundred and forty thousand square miles known to have received a deposit of an inch or more of ash. But his figure, large as it is, is not to be taken as an estimate of the area covered, for it is admittedly based on the incomplete data available from a country only partially explored. Near the crater, deposits of this material three hundred feet thick have been reported. This eruption though geologically recent, occurred long before historic records began in North America. Capps[17] estimates that it is fourteen hundred years old. It is evident, therefore, that the forces of erosion have had full sway. Judging from our experience at Kodiak, vast quantities of this material must have been carried out to sea by erosion. Its original mass may have been much greater than present estimates would indicate.

It is to this region that one must look for aid in predicting the course of events in the Katmai district. Here the succession of events, in the course of revegetation, must have been somewhat similar to that in our area. Unfortunately, however, this region has not yet been studied botanically, and little is known about its revegetation. In many places the ash deposit is covered with a layer of peat, which reaches a thickness of seven feet as reported by Capps[17]. But in other places, the

[16] Capps, S. R. An Ancient Volcanic Eruption in the Upper Yukon Basin. U. S. G. S. Prof. Pap. 95 D. 1915.

[17] Capps, S. R. An Estimate of the Age of the Last Great Glaciation in Alaska. Jour. Wash. Acad. Sci. 5: 108-115. 1915.

ash remains bare with only the beginnings of revegetation. It should be possible by studying the transitions from one condition to the other, and by examining the peat, to gain considerable information concerning the sequence of events. It is very much to be hoped that results of such a study may soon be available.

ASH POOR IN NUTRIENT SALTS.

Before taking up the discussion of the details of the recovery of vegetation at Kodiak, it will be advisable to consider the chemical character of the ash. I find that there is a widespread idea that this remarkable recovery is due to some "fertilizing" property in volcanic ash which stimulates plant growth. This idea owes its origin to the well known fertility of soils derived from the weathering of volcanic rocks, especially from basaltic lava flows. In the United States particularly, the fertility of the soils derived from the great Columbian lava flows of Oregon and Washington have been so much advertised as to have influenced the thinking of many people. Even so competent an authority as Russel says, concerning a fall of volcanic ash in the west: "This last light shower of dust * * * * added many thousands of tons of fertilizing material to the region on which it was spread."[18] A little reflection will convince anyone, however, that there is a vast difference between a fresh deposit of raw ash and a soil derived from the slow weathering of lava through perhaps a million years. There was, moreover, a great difference in the initial chemical composition of basic lava like the basalt of the Columbian region and the acid ash deposited at Kodiak. Whereas the one contains considerable quantities of the salts required for plant growth, the other, as shown by the subjoined analysis, is very low in such compounds,* having in fact practically

[18] Russel, I. C. Volcanoes of North America, p. 287.

* Analysis made by Elton Fulmer, State Chemist of Washington for the United States Department of Agriculture. Sample was collected at Kodiak and consisted of all three layers mixed so as to give a fair average of the conditions encountered by plant roots.

Loss on ignition	0.65%	Lime (CaO)	3.80%
Silica (SiO_2)	72.16%	Magnesia (MgO)	0.47%
Ferric oxide (Fe_2O_3)	2.85%	Soda (Na_2O)	3.86%
Manganese oxide (MnO)	0.41%	Potash (K_2O)	2.43%
Titanium oxide	trace	Sulphuric acid (SO_3)	0.20%
Alumina (Al_2O_3)	13.85%	Phosphoric acid (P_2O_5)	0 36%

Remarks: The ash is highly magnetic; in all probability some of the iron present is magnetic.

the composition of pulverized granite. If one will compare the soils derived from the weathering of granite with those formed from basalt, he will see how inapt is the comparison of volcanic ash with such soils, for granite forms a notoriously poor soil.

More direct evidence than the reasoning from the analysis, however, may be had from the results of attempts in laboratory and field to grow plants in the ash, which will be reported in a special paper. In the present connection it is sufficient to say that when such a plant as wheat is grown in the ash, it starts well and grows so long as the supply of nutriment stored in the seed holds out, but when this is exhausted the plant soon starves to death. While it is perfectly true, therefore, as has been stated elsewhere, that the ash has improved the pastures at Kodiak, this is not attributed to any chemical effect, but is to be accounted for largely by its action as a mulch, which, by smothering the smaller herbs, provided improved conditions for the stronger plants which pushed up through it; and second, by the improvement in the physical condition of the soil when mixed with the ash, for the old soil was inclined to be heavy, mucky, and poorly drained.

CLIMATE OF KODIAK REMARKABLY MILD.

It will also be advisable before taking up the botanical features of the recovery, to discuss the climate of the district, for this has an important bearing on the course of revegetation, and like the chemical composition of the ash is subject to much misconception by those who have not given it especial attention. The Government Experiment Station at Kodiak has for a number of years kept records of temperature and precipitation which are summarized herewith (Tables I and II). These records were supplemented during the field season of 1916 by observations of some features of more especial importance to the growth of plants. The instruments used were a Friez Hygrothermograph, a battery of non-absorbing porous cup atmometers placed in various habitats, a rain gauge, and a barograph to assist in forecasting the weather, a very important item in work involving so much use of boats in the open. The continuity of the records was made possible by the assistance of my wife, who, as the silent partner in all the investigations, has contributed greatly to whatever merit the work may possess.

Kodiak has an extreme case of an "insular climate" conditioned not only by proximity to the sea, but also by the Japan current, which has the same effect here as has the Gulf Stream on Ireland. This produces a remarkably equable and very moist climate, in which, despite the high latitude (58°), the seasons are subject to considerable variation from year to year, as may be seen from the summarized data.

TABLE I.
Summary Monthly Mean Temperatures, Kodiak.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Highest of Record	35.9 (1912)	39.1 (1905)	40.4 (1905)	38.6 (1905)	45.6 (1906)	54.3 (1905)	59.4 (1899)	58.2 (1899)	51.7 (1906)	44.5 (1906)	38.4 (1899)	36.1 (1914)
Lowest	22.6 (1906)	26.0 (1907)	29.8 (1911)	30.8 (1911)	40.1 (1911)	45.7 (1911)	48.8 (1908)	52.0 (1908)	45.7 (1908)	37.8 (1908)	31.9 (1900)	28.0 (1911)

TABLE II.
Summary Monthly Precipitation, Kodiak.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Highest of Record	12.92 (1912)	8.16 (1912)	7.46 (1900)	6.67 (1912)	14.59 (1912)	11.21 (1914)	6.64 (1908)	9.20 (1906)	10.00 (1901)	13.52 (1914)	9.32 (1911)	11.10 (1901)
Lowest	1.00 (1907)	0.30 (1901)	0.00 (1907)	2.10 (1914)	3.01 (1911)	1.63 (1908)	0.82 (1899)	2.37 (1899)	1.50 (1906)	1.85 (1900)	2.28 (1900)	1.88 (1905)

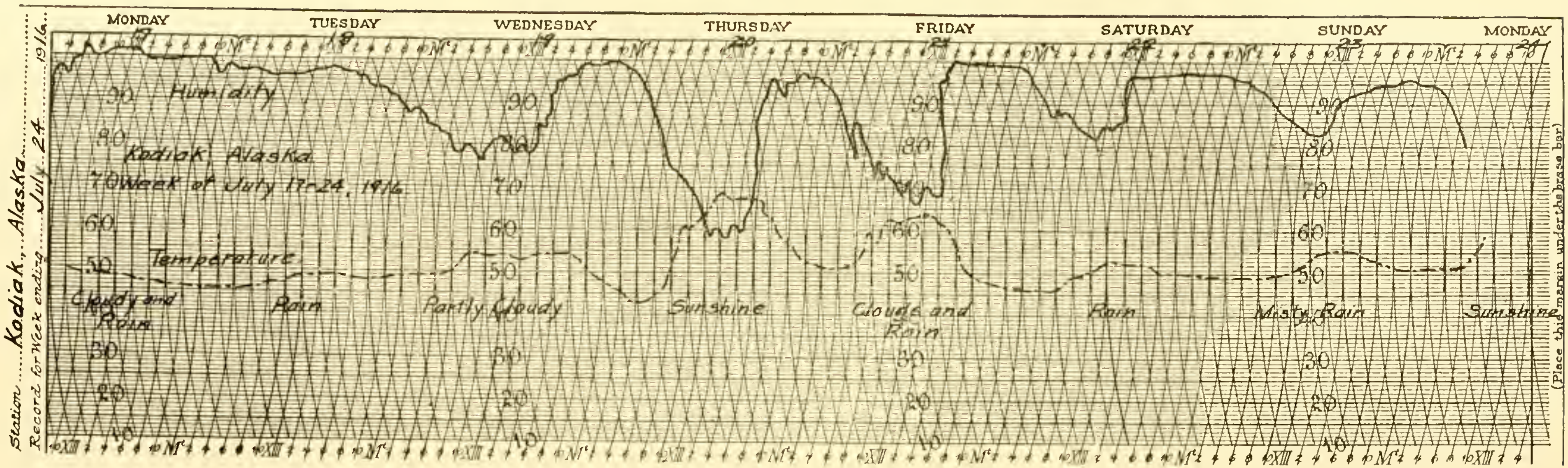
The extreme minimum temperature recorded is −12° F. But many winters pass in which the temperature does not reach zero. The extreme maximum is 82°. There is great variation in the time of the first and last frosts and the record is not long enough to give data for reliable generalizations. But the last killing frost usually occurs in May, and the first killing frost in October. The growing season is, therefore, in the neighborhood of one hundred and fifty days, which will compare favorably in length with that of the northern states of the Union.

The total precipitation averages approximately sixty inches per annum. Although heavy rains (1.50 inches) are known, the rainfall comes largely in the form of fine mist which, while holding the air at the point of saturation for days together, accumulates very slowly. For this reason, tables of precipitation and temperature are apt to give a very incorrect idea of the climate.

There are about one hundred and sixty days with precipitation of one one-hundredth of an inch or more and many more days with low-hanging clouds. The persistent cloudiness greatly cuts down the amount of radiant energy reaching the ground. But the long hours of daylight throughout the growing season, with practically continuous illumination for a month in mid-summer, must largely compensate for the weakness of the light. Measurements of the radiant energy received in this area, if compared with similar measurements in an alpine area of lower latitude such as Pike's Peak, would form an exceedingly interesting and instructive exhibit, for as is well known, the plant societies of the two regions have many resemblances. It was hoped at the beginning of the work that such records could be obtained, but conditions incident to the war made it impossible to procure the necessary instruments.

EVAPORATION VERY LOW.

Probably the most significant records available for estimating the conditions under which the plants grow, are those of the hygrothermograph and of the atmometers. The record of the hygrothermograph for a typical week, July 17-24, 1916, is reproduced herewith. In addition, the records of the ten weeks, including the best of the growing season, during which the instrument was operated at Kodiak, may be summarized. During this period temperatures above 70° F. were reached only five times, for an hour or two only in each case. The highest temperature was 73.5°. The lowest was 40°, but temperatures below 45° were reached twenty-six times and sometimes were held for a number of hours. The lowest relative humidity recorded was 47%, and only on fifteen days was the humidity reduced to less than 60%. More significant is the fact that during twelve hundred and sixty hours or 75% of the period, the humidity stood above 80%. Inasmuch as this record was taken in the open in an instrument shelter of



THE HYGEOTHERMOGRAPH RECORD FOR A TYPICAL WEEK.
Humidy in percent, temperature in degrees Farenheit.

standard type, where humidity was at a minimum and evaporation high (see below), it is evident that there was small danger of seedlings suffering from drought in the field.

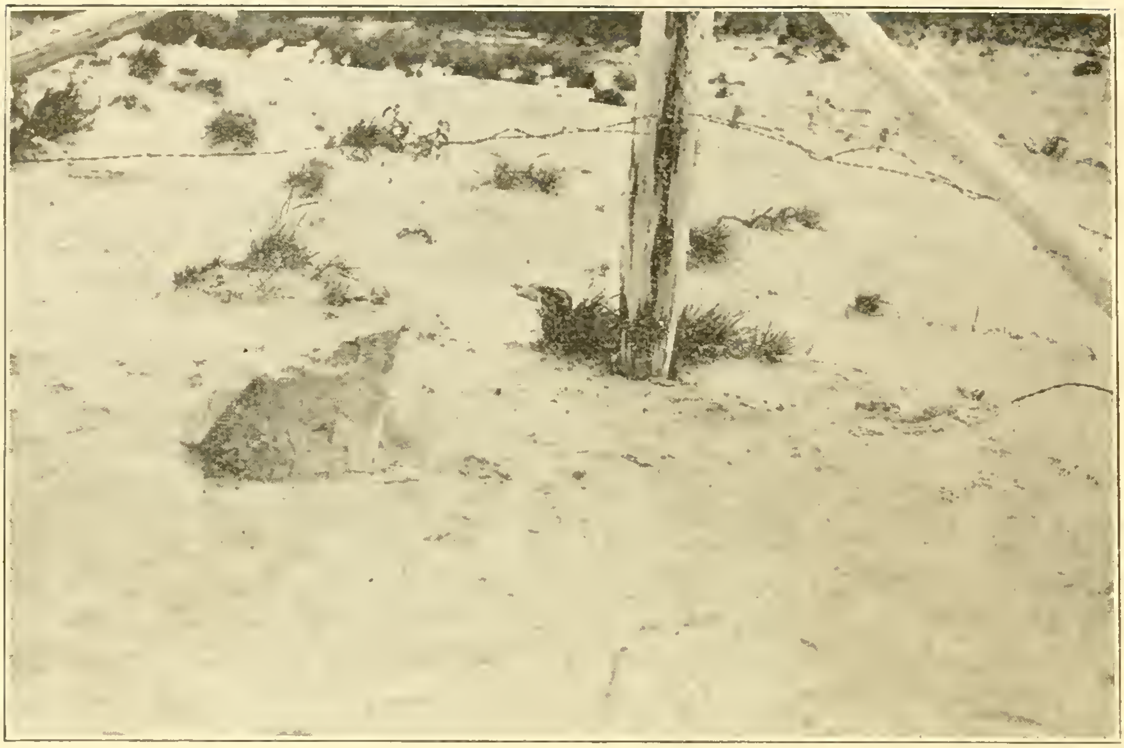
The evaporation data were taken by non-absorbing cylindrical atmometers furnished by the Plant World Company. One was located in an open school yard beside the other instruments, a second in a dense growth of young spruce trees near Vegetation Station 11, a third in an open glade formerly occupied by a small bog (Vegetation Station 12), a fourth on a steep mountain side in the Calamagrostis-Alnus association at an altitude of two hundred and fifty feet, (Vegetation Station 28), and the fifth on the summit of Pillar Mountain, a bare wind-swept situation at an altitude of twelve hundred feet (Vegetation Station 17, see page 26). The average daily evaporation rates from these instruments, corrected by the coefficient supplied with the cups to reduce it to that of the standard instrument, is given in Table III. The table gives both the absolute rates and the ratio of evaporation in the different habitats.

Table III. Evaporation Data at Kodiak.

Evaporation from white cylindrical porous cup atmometers reduced to standard values.

Station	Period	Average Daily Evaporation	Percentage
Base, Schoolyard Kodiak, alt. 20 pp.	67 days	6.83	100
Grass covered mountain side, alt. 375 pp.	66 days	6.30	94
Summit Pillar Mountain, alt. 1200 pp.	66 days	9.79	146
Opening in forest formerly occupied by small bog.	67 days	2.64	39
Dense forest, young trees	67 days	2.22	33

The data shown in Table III need no comment, except in the case of the mountain summit. This station was bathed in thick fog for many days when the lowland was clear. As there were usually high winds on such days, the evaporation on the lowland was often considerable, when moisture was condensing around the mountain top. Since, therefore, the period of evaporation on the summit was much shorter, the comparative rate, when evaporation occurred at all, must have been considerably greater than is indicated by the results, notwithstanding the fact that this station had a much higher rate than the base station. This is probably of great importance



Photograph by R. F. Griggs

VEGETATION STATION 18, AUGUST 11, 1915.

A fence corner bare of vegetation except for a few stalks of Polytrichum and the bunches of grass around the post.

Photograph by D. B. Church

THE SAME STATION A YEAR LATER.

August 27, 1916. Seventeen seedlings of lupine had come up, also several grass seedlings. The clumps of grass outside the fence which prove to be *Deschampsia cæspitosa* have fruited but are not much extended.

in determining the character of the vegetation in the station, which, before the eruption, was occupied by a typical arctic-alpine heath. Instrumental records giving comparative hourly evaporation rates in such stations and the lowland would be of great interest.

More significant than the differences between the different habitats is a comparison of the evaporation rate of the region as a whole with that of other regions. Unfortunately, however, comparable data are very scanty. Briggs and Shantz

Photograph by R. F. Griggs

THE SAME STATION TWO YEARS LATER.

September 12, 1917. All but one of the lupines winter killed but many new ones have started. Many clumps of *Agrostis hiemalis*. Old clumps of grass much enlarged.

have shown[19] that records of the different types of instruments employed for measuring evaporation are not closely comparable. Although porous-cup atmometers of the general type used in the present investigation, have been employed for a number of years in ecological research, it is only recently that the instrument has been sufficiently perfected to correct the errors

[19] Briggs, L. J., and Shantz, H. L. Comparison of the Hourly Evaporation of Atmometers and Free Water Surfaces with the Transpiration Rate of Medicago sativa. Jour. Ag. Research 9: 277–292. Pls. 4–6. 1917.

incident to exposure under different climatic conditions. The instruments we used were of the non-absorbing or "rain-proof" type, but the new spherical cups had not yet been supplied to correct for variations in the angle of incidence of the sun's rays. The following example will, however, convey some idea of the relative evaporation at Kodiak and in the northern United States. Transeau[20], in the pioneer work of this sort, found an average daily rate of evaporation of 19.72 ccm. at his base station, the Garden of the Carnegie Institution at Cold Spring Harbor, Long Island, New York, as compared with 6.83 ccm. at Kodiak. This station at sea level near the ocean is in a general way comparable with Kodiak. But his instruments were of the old rain absorbing type, and the cup was set close to the ground, whereas ours was set about a meter above the ground. Both of these facts would tend to increase the difference between the rates at the two places.

THE VEGETATION STATIONS.

At the inception of the work, it was recognized that the restoration of the plant cover was a process that would probably require several decades for its completion. It was deemed essential to a proper record of the progress of events that a series of permanent vegetation stations of some sort be established in which the future student might find areas whose exact history is known from the period of the eruption. The selection of the type of such vegetation stations and the best way of locating them were, therefore, among the first problems to be solved at the beginning of the investigation.

In the course of the work about one hundred definite vegetation stations have been established, partly in the vicinity of Kodiak, partly on the mainland. Some of these have already served the purpose of their establishment and observation of them has been discontinued. At others the anticipated beginnings of vegetation will not start for some years. Repeated observations through three consecutive years have now been made at more than half of these stations. In some cases the photographic records include five years, dating back to 1913 or even to 1912.

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[20] Transeau, E. N. The Relation of Plant Societies to Evaporation. Bot. Gaz. 45: 217-231. 1908.

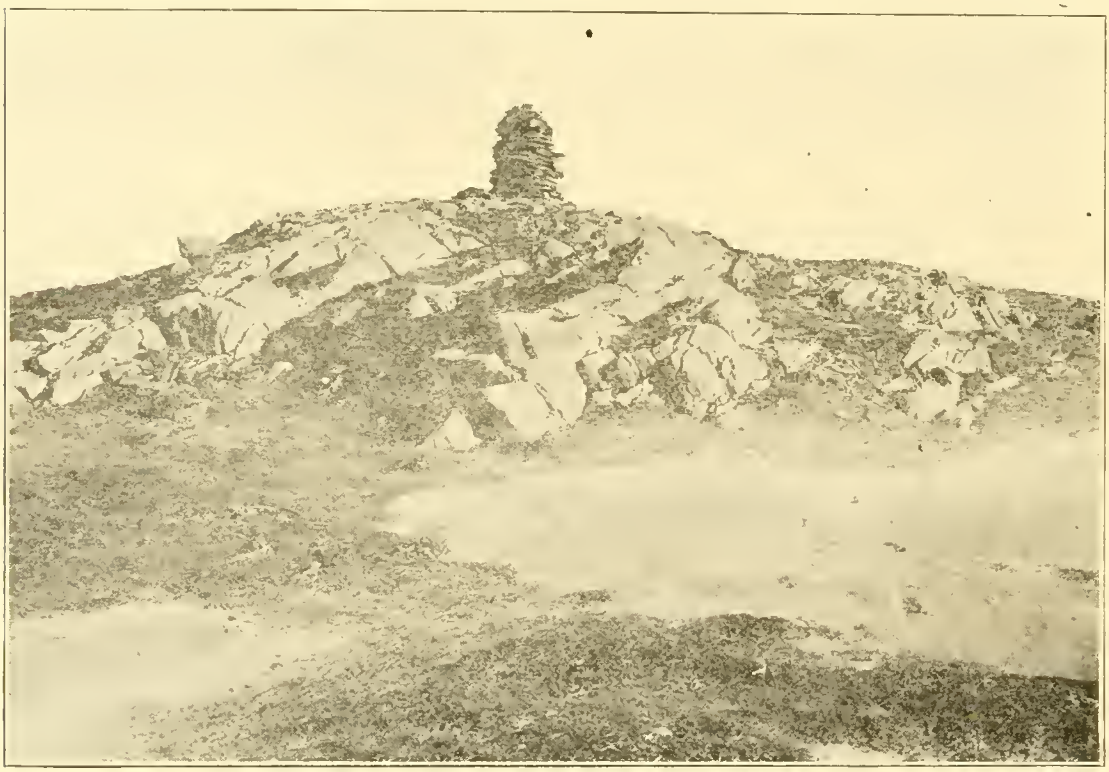
The changes that have already occurred at some of these vegetation stations have been of great service in interpreting the progress of revegetation, and the value of the record will be materially increased with the lapse of time. (See pages 22 and 23). For the present it is not considered advisable to undertake the expense incident to the publication of this rather extensive record. Later developments, however, when revegetation shall have made more progress, may very probably make it advisable to publish the record, in part at least. For the present I have contented myself with inserting, after such photographs of the stations as could be suitably used to illustrate the article, the station number, as for example on page 47 (Vegetation Station 11).

THE DIFFICULTY OF MARKING VEGETATION STATIONS.

The selection of vegetation stations, which can be easily located in a country without the landmarks that grow up with human occupancy, was found to be a problem involving some considerable difficulty. Many of the most interesting situations observed were located in the depths of the forest far from a trail, or in the middle of a mountainside in a spot which one could hardly hope to find again himself, much less describe on paper so that another might go to it.

It will be seen at once, therefore, that the limitations thus imposed, restrict the selection of vegetation stations so that those chosen cannot be claimed to present an ideal set of stations covering all sorts of habitats within the area. Since the population is primarily maritime, the country around Kodiak, despite the fact that it has been occupied since before the time of the American Revolution, is almost untouched by the hand of man, and landmarks are very few. I have made much use of such landmarks as are available, however, for the large majority of the stations have been related to some monument of human occupancy. Aside from such places, the number of situations which can be relocated with ease is rather limited. Several of the stations have been placed on a narrow neck connecting a peninsula with the mainland. Mountain and hill tops may be located with ease and were much used. Such places are, however, to a large extent just the places most unfavorable for returning vegetation. Any station which can be seen for a distance is necessarily in an exposed situation, and wind-sweep is such a factor in retarding revegetation, that such places will be the last to be occupied by plants, whereas one would wish to place stations in the places that will be first taken up by new plants, if he could describe locations therein.

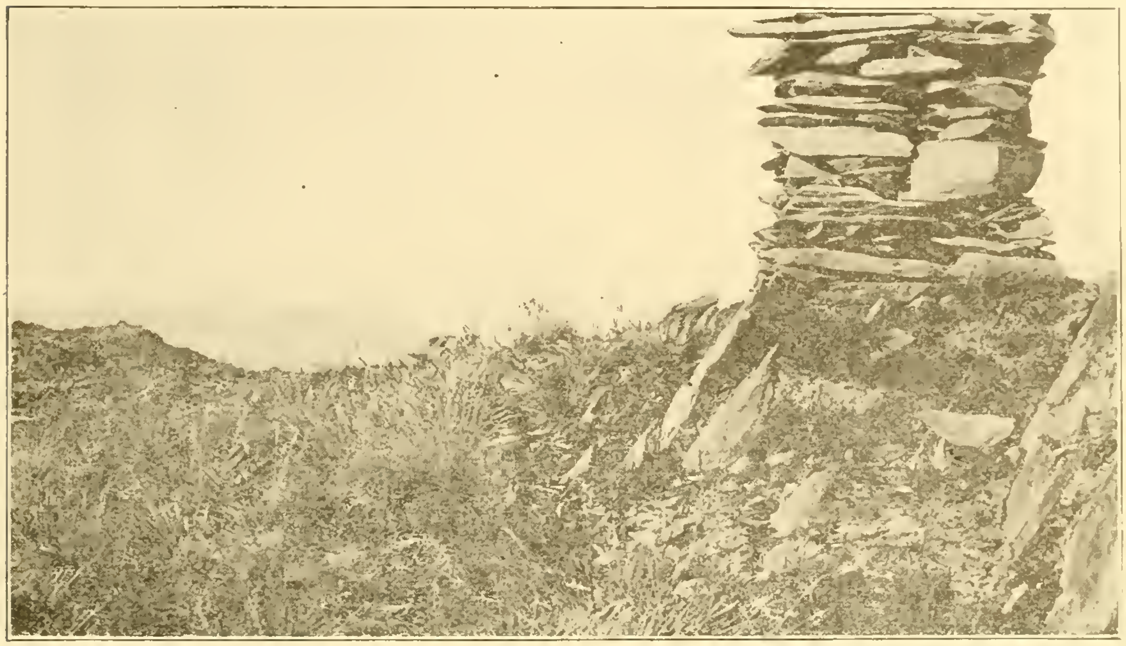
The problem of marking the stations so that they may be found again is also one of considerable difficulty. If one intended to follow the progress of returning vegetation only for a year or two, the customary wooden stakes would serve very



Photograph by D. B. Church

THE SUMMIT OF PILLAR MOUNTAIN.
Vegetation Station 17.

well. But where one wishes to follow the succession of vegetation, as in the present case, the stations should be so marked that they can be visited a hundred years hence, and this is a much more difficult matter. It was planned in advance to mark the stations with iron pins, but when it was observed that the natives have a habit of gathering up any pieces of old iron that might prove useful, such marks were seen to be even less permanent than wooden stakes. In no case where the stations are located beside a fence, abandoned house, or other human improvement, will the marker last for any such period. It has been necessary to trust that the land-line, represented by the fence, would be maintained and the fence renewed. Where the line so chosen is the line of a government reservation, it is reasonable to expect that the line will be maintained, but in other cases it is more doubtful. In many cases stones were set on the ground to mark the position of the stations. These are subject to few natural disturbances, except movement by masses of snow, which were not to be expected in the stations



Photograph by R. F. Griggs

DETAIL FROM SAME STATION AT END OF FOURTH SEASON.

Trisetum spicatum and *Agrostis hiemalis* cover the ground. *Festuca* (ovina) *brachyphylla*, the vernal fascies, and the other alpine plants mentioned in the text, (p. 30) are not conspicuous in the photograph.

chosen. If not removed by hunters, they should remain in place for many years. But around Kodiak some of them had been picked up by the curious within a few weeks from the time they were set.

On the mainland, it seemed necessary to use the deserted houses at Katmai village for markers in the absence of almost all other landmarks. But they are falling into ruin so rapidly that there will be little left after ten or a dozen years. Fortunately, however, the stove pipes, shown in the photographs, are heavy wrought iron affairs which will stay in place for a long period. Two stones were found in the cemetery and from these, a rough system of triangulation was made, tieing together all the stations within sight of them.

Such definitive data as could be drawn from the immediate vicinity were in most cases supplemented by compass bearings on distant objects. When a station commands a view of the surrounding mountains or similar features, such bearings are the most permanent marks that can be used for its location. In other cases the bearings were taken on blazed trees, which, if uncut, will stand for several centuries, while even if cut, the stumps will persist for a long while. Theoretically compass bearings in two directions fix the location of any point, but in practice the method is open to considerable objection. It is very easy to take compass bearings from any point, but it is much more difficult to return with the compass and pick up a station from the readings. Pocket compasses, with which the bearings were taken, are not instruments of precision, moreover, and it is doubtful whether the instrument would always duplicate its readings at the same station. Nevertheless, it is believed that such compass bearings will be of considerable assistance in locating the stations after the face of the country shall have undergone considerable change.

ADVANTAGES OF PHOTOGRAPHS OVER HAND MAPPED QUADRATS.

The most satisfactory means of locating a station, considering all things, is a photograph taken so as to show the relation of the station to distant objects. Such bearings fix the position of the camera with a considerable degree of precision. In some cases, it has been found desirable, for example, to duplicate a photograph taken soon after the eruption, which came into our possession with no data as to location except that furnished by the picture itself. Where the general location of the picture could be guessed, it was found possible to fix its exact location within a very few feet. It is believed, therefore, that the photographs are the most valuable means of locating the stations, containing as they do, much data not susceptible of description. (See pages 4 and 5).

In planning for the work before reaching the field, it was assumed that the best form of vegetation station for the work would be the meter quadrat developed by Clements. Experience showed, however, that the ground covered by a definitely located photograph makes a more satisfactory station. The photograph possesses several distinct advantages over the method of laboriously mapping square quadrats employed by Clements. (1) It has unlimited flexibility as to size. It is as readily adaptable to the minutest group of seedlings as to a whole hillside (See page 30 and page 40). (2) In every case it records conditions with a fidelity to detail unattainable by any other method at anything like the same scale. One has only to decide with what detail a given situation should be

Photograph by R. F. Griggs

ALDER SEEDLINGS COME UP IN THE ASH AROUND THE FALLEN FRUITS, NATURAL SIZE.

recorded, and set up his camera at a distance suitable for rendering that detail. (3) In all but the largest scale pictures the record, by including some prominent feature in the landscape, can be made to carry its location with it more accurately than any ordinary verbal description. (See page 39). (4) It eliminates the personal equation, which becomes very large in mapping even if it is attempted to include every detail. (5) It shows many things not noticed by the observer. It often happens that the development of vegetation occurs along unexpected lines, so that objects which at the beginning were included merely incidentally turn out to be of first importance. Station 17, for example, (see page 26) was located for the purpose of recording the return of vegetation in the foreground and no special attention was paid at the time of its establishment to the condition of the mound in the background. There was no change in the special ground designated as the station until two years had elapsed, but a striking invasion occurred the following year in the background, a detail which is reproduced on page 27.

Photograph by R. F. Griggs

SEEDLINGS OF RUBUS SPECTABILIS AND CHAMÆNERIUM AUGUSTIFOLIUM.

Starting in the ash beneath the shelter of the spruce trees whose needles cover the ground.

After this had taken place, it was found possible to go back to the first photograph and identify every one of the clumps of grass which sprang up so conspicuously the following year, ascertaining exactly what had happened as accurately as though a complete census of the area had been taken in the first place. (6) Beside providing much better records, photographic methods are much more rapid and, therefore, much less expensive than platting. This may not be apparent to one who does his work near home in vacations, but where considerable sums must be spent in traveling expenses and the season for work is short, it becomes an extremely important item. (7) Photographic records may readily be reproduced at small expense, but hand made maps could be duplicated for the use of others only at considerable cost. The loss of a set of quadrat plats might upset the whole work, but a set of field prints, if lost in the vicissitudes of exploration, would be missed only temporarily.

REVEGETATION DUE TO RECOVERY OF OLD PLANTS.

It was supposed by all who visited Kodiak during the first two seasons following the eruption, that the smaller herbaceous plants had been practically exterminated, except for a few individuals so situated that they could easily grow through the ash layer. Consequently, when the remarkable new growth of succeeding seasons was observed, it was natural to suppose that the new vegetation must consist of new plants which had started in the ash from seed.

Field study, however, at once showed the incorrectness of this view, for even the most superficial observation showed that at the beginning of the fourth season (1915), there were practically no seedlings, most of the new plants being directly traceable to the old roots. The most striking large scale demonstration of this fact is furnished by the condition of a field on the Frye-Bruhn ranch, south of Kodiak, which was plowed before the eruption. Where cultivation destroyed the weeds, no new vegetation appeared for five years, but the plants of the uncultivated land all around came up in undiminished vigor and completely covered the ground. The difference between plowed and fallow ground is so marked that it is conspicuous as far as one can see. (See pages 32 and 33).

Excavation of the underground parts of the new vegetation always revealed either a characteristic "two-storied" root system, or definitely showed the connection of the new stalks with the old soil in those plants which do not put out new roots at the surface of the ash.

PLANTS RESURRECTED AFTER THREE YEARS BURIAL.

The belief shared by all observers, that the herbs which did not reappear during the first season after the eruption had been killed, was, of course, due to the presumption that a comparatively short period of covering would prove fatal at Kodiak

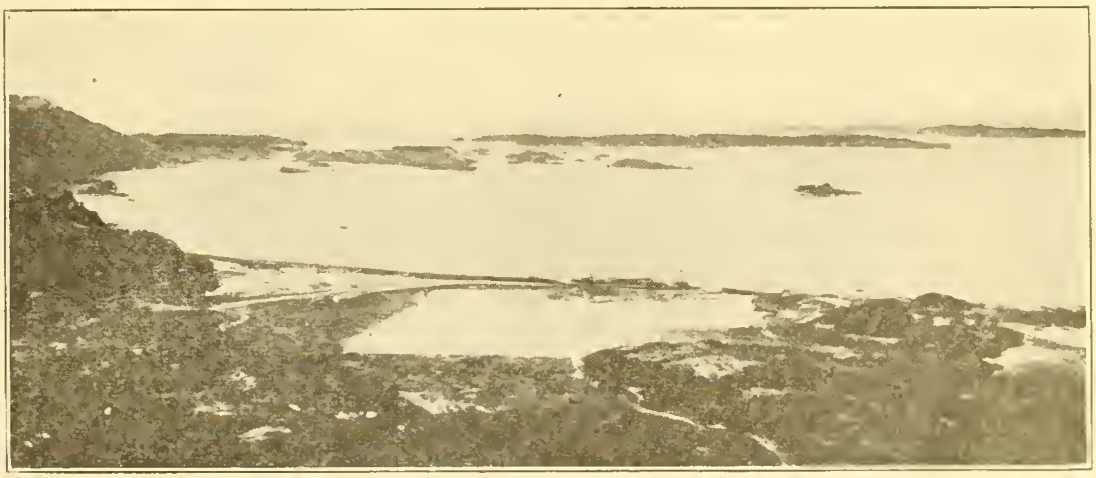
Photograph by D. B. Church

A PLOWED FIELD, PART OF WHICH WAS CULTIVATED JUST BEFORE THE ERUPTION.

The line between cultivated and fallow ground remains perfectly distinct after four years. Cultivation just before the eruption destroyed most of the weeds and no new ones have been able to start. The uncultivated land has grown a mass of fireweed, whose bloom is conspicuous for miles—illustrating the importance of residual vegetation.

as it would in the United States. The death of grass in a lawn, where a board is allowed to lie for a few weeks, is familiar to all. It was supposed that burial under a foot of volcanic ash would have the same effect. I was, therefore, very much astonished to find that the plants at Kodiak were able to recover from such burial. Later observations, however, showed that the recovery at Kodiak was altogether eclipsed by that shown in some areas on the mainland, where many plants survived a much deeper burial for a longer period. For there many plants were found to have recovered after a burial of three years under an ash blanket several feet in thickness.* Definite proof of recovery after such an interval was observed in only one instance at Kodiak, but the manner of reappearance of numerous species strongly suggests that recovery after such prolonged dormant periods was as important a feature at Kodiak as at Katmai.

A number of the humbler species of plants, which could not penetrate the ash, seemed in 1913 to be practically exterminated. But some of these have reappeared in such a way as to suggest



Photograph by D. B. Church

THE SAME PLOWED FIELD FROM A MOUNTAIN TOP.

that the old stocks, from which the new shoots have come, lay dormant for two or three years before putting out any new growth. *Rubus pedatus*, for example, which formerly carpeted the forest floor was not seen at all in 1913. In 1915 a few plants could be found by search. But in 1916 it was common in many places, growing as vigorously as before the eruption. Of Vitis-Idaea only a single sprig was seen in 1913. In 1915 it was not uncommon, and in 1916 it was abundant. No specimens whatever of Drosera were seen around Kodiak until 1916, when a single individual was detected. *Rubus chamaemorus* likewise was not seen at all until 1916, but then was fairly common in a number of places, some of which had been repeat-

* This matter is discussed in detail in a forthcoming paper dealing with the recovery of the mainland plants.

edly collected over in previous years. Examination showed that all of these plants were hold-overs rather than seedlings. It seems hardly credible that we could have been so careless as to have overlooked them if they had put forth new growth in the previous years, for when found they were growing vigorously, flowering and fruiting freely.

Photograph by B. B. Fulton

FIREWEEDS INJURED BY SAND BLAST.

The few fireweeds which remain in the plowed field shown on pages 32 and 33 have had a hard time of it, being lopped over and cut to pieces or plastered up by the sand blast.

Although this situation would be difficult to account for otherwise, it may not be justifiable to assign resurrection of dormant roots as the cause for the reappearance of these species on such slight evidence. But in *Equisetum arvense* crucial proof, of the ability of the underground parts to retain their vitality when buried, was furnished when I found an old rhizome of this species which I had exposed in excavation in 1915 that had put forth new shoots the following year. This had been lying water-soaked in an old bog for three years. When dug up, all of the plant remains, of which it was a part, were blackened by bacterial action and were unhesitatingly pronounced dead. The circumstances were such as to leave no manner of doubt that the new growth had come from part of this supposedly dead material, for the new shoots were coming

Photograph by R. F. Griggs

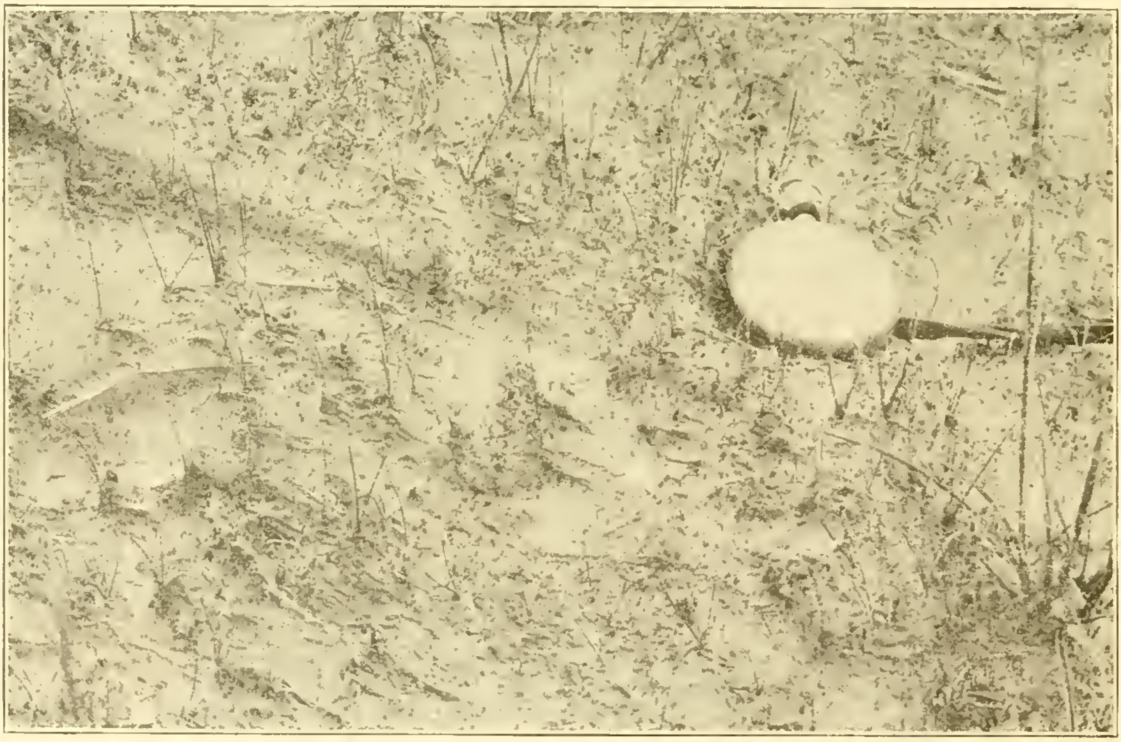
RUBUS PEDATUS GROWN THROUGH THE ASH.

This species did not reappear in numbers until three years after the eruption.

out of old rhizomes still embedded in the clods, as I myself had removed than the year before in establishing one of the vegetation stations. The material was, moreover, lying on a bare ash flat without other vegetation for many feet round about.

DIFFICULTY OF STARTING SEEDLINGS IN THE ASH.

More significant, perhaps, than negative observations indicating the absence of seedlings, are the results of the attempts that have been made to seed down various ash covered areas. At the Government Experimental farm at Kalsin Bay a number of pasture grasses were planted soon after the ash fell. The seeds came up well, giving an almost perfect stand in nearly every case. Where heavily manured, many of the plots have continued to do well, and some of them have formed a good turf on the ground.



Photograph by R. F. Griggs

A TIMOTHY PLAT THREE YEARS OLD.

Sowed in the ash soon after the eruption, the seed came up well and most of the plants are still alive but have made no growth. Contrast with the grass come up from old roots, shown on page 7.

Where planted in the untreated ash or with little fertilizer, different species have behaved differently. In some, most of the plants were overwhelmed while yet small, but a few individuals managed to get a good start and are now strong enough to hold their own against the undermining wind, while in others most of the original plants have persisted, but have made only very slight growth. On the timothy plot, for example, most of the plants are still living, but after four years are only three inches tall. (See page 36). The contrast offered by such plants with grasses which have come up from the old roots (see page 7) is too striking to need further discussion. The importance of surviving plants in the revegetation cannot be overestimated. Where for any reason none of the old plants persisted, the ground remained as bare as when the ash first fell, for no seedlings were able to start in such places. The reason did not lie in the sterility of the ash, for as will be seen, this can be overcome where the surface is stable enough to give the young plants a chance. The trouble is that the ash, having the consistency of fine sand, is kept moving so rapidly by the wind that seedlings have no chance except in sheltered places.

Photograph by R. F. Griggs

ASH DRIFT LODGED BEHIND FIREWEEDS.

The drifts bear every appearance of snow banks. The fireweed endured such burial for three years but then succumbed.

ASH DUNES LIKE SNOW DRIFTS.

One of the most striking examples of the effect of wind action was in the plowed field above referred to. Here every passing gust of wind picked up a cloud of dust, while the heavier sand particles were swept along the ground. Volcanic ash is composed of angular fragments of glass far sharper than ordinary sand. The sand blast was thus very hard on all plants exposed to it. The few weeds which escaped the plow and came up through the ash in the open part of the field were nearly destroyed by the sand blast. They were all lopped over before the wind, and their lower leaves either cut to pieces or so plastered with the drifting ash as greatly to interfere with their functions. (See page 34). Where the plants stood thicker, on the other hand, at the edge of the field, they checked the moving sand which formed conspicuous drifts behind them. (See page 37). These drifts follow exactly the familiar forms of snow drifts. Some of them are several feet deep, forming shifting dunes very like those of the sea shore. Where such dunes were caught by growing vegetation, the plants have had a severe struggle to maintain themselves. The more rapidly new growth was pushed out beyond the engulfing sand, the more drift did the plants catch and the higher must they grow

Photograph by R. F. Griggs

HILLOCK OF DRIFTING ASH CAUGHT BY A WILLOW WHICH IS OVERTOPPING THE OBSTRUCTION BY ITS GROWTH.

to clear it. Many plants in this way surmounted drifts much thicker than they could have penetrated if they had accumulated all at once. In some cases, as in the willows, where the plants could readily send out new roots into the sand, they are probably little the worse for their experience. (See cut above). But plants like the fireweed, which have no such capacity, were soon so deeply buried that it overtaxed the conducting system to maintain the connection between the leaves and roots. At the edge of the field in question, they held out for four seasons and at the end of 1915 were apparently unaffected by the struggle. But the next spring they failed to come up, showing that the dune had finally been too much for them. It is obvious that no new plants can gain a foothold so long as such conditions prevail. Any seedlings that start are either promptly undermined, blighted by the sand blast, or buried beneath the drifts.

A DUNE OF WIND-BLOWN ASH NEAR KODIAK.
The rapidly shifting surface makes it impossible for plants to start.
(Vegetation Station 59).

QUICKSANDS IN THE SWAMPS.

Quite a different set of conditions prevail in the numerous swamps, shallow ponds and tundras which were formerly common. Here also the deposit of ash has been increased by secondary accumulations, in this case brought down by the streams. There is no tendency for this ash to blow about for it is kept constantly soaked. It is, moreover, of quite a different physical constitution from the loose sand of the dunes. It should be explained that there was a marked difference in consistency between the three layers of ash as they fell.

Photograph by B. B. Fulton

AN ASH-FILLED POND.

The circle of Menyanthes (center) marks the former edge of open water in which grew the waterlilies. The outer zone was a sphagnum bog. The bog was destroyed but the aquatics have come through the ash. (Vegetation Station 13.)

The bottom (gray) layer was made up of fairly large particles, giving the deposit the character of fine sand; the second (terra cotta) layer was very much finer, almost all dust; while the top layer (gray) was similar to the first but very much finer. The top layer has almost everywhere blown away, leaving the present surface of the ash composed usually of the middle brown layer.

Because of the fineness and angularity of the particles, the physical properties of this layer are very peculiar. When dry, it is all blown away in a cloud of dust by the gentlest breeze. But when moist, the particles settle close together, interlocking one with another, till they form a hard compact terrain which coheres almost as though the particles were cemented together. If more water is added there comes a point at which the interlocking particles are floated free from each other, and the mass suddenly changed from a rigid solid to a perfect liquid. This layer, therefore, in the wet climate of Kodiak, is little affected by wind action, but is rapidly eroded by the streams, and it is this fine material especially which has accumulated in the ponds and tundras, sometimes to the depth of several feet. In such deep beds, the facility with which its condition changes from solid to liquid becomes a matter of considerable moment. This change may often be brought about suddenly by stirring the mixture, without the addition of more water. It will be seen that there are here conditions favorable to the formation of dangerous quicksands. In the examination of such places, one often finds on retracing his steps that the place, over which he came on hard ground but a moment before, has become a soupy liquid under the disturbance caused by his tread. Several men have been seriously mired in such places.

POND PLANTS LARGELY SURVIVED.

Where the ash deposit in the filled ponds is wet enough to remain in a semi-fluid condition, the original aquatic vegetation has to a large extent recovered, and is thriving as before the eruption. A little pond in the forest north of Kodiak (see page 40) will furnish a good illustration of the situation. So much ash has been washed into the pond that it is completely filled up, so that the surface remains dry and hard during dry periods. In the center, formerly covered with open water, are water lillies (*Nymphaea polysepala*) thriving apparently as well as ever, for they flower and fruit abundantly. Surrounding the former open water is a zone of buckbean (*Menyanthes trifoliata*) likewise in good condition. Here and there are also clumps of Mare's tail (*Hippurus vulgaris*). The first and last are apparently spreading merely by vegetative means, but there are many seedlings of Menyanthes on the bare surface round about, which give every indication of establishing themselves.

BOGS PRACTICALLY DESTROYED.

The ring of buckbean was formerly surrounded by a Sphagnum bog or tundra. This, like all the bogs, was practically exterminated by the eruption. Sphagnum, and the plants associated with it, are of such weak growth that they were not

Photograph by R. F. Griggs

A CARPET OF HORSETAIL IN A FORMER BOG.

Many of the old bog areas have come up in a pure stand of Equisetum arvense which has kept the ash from blowing away and serves as a "nurse" for seedlings of other plants.

able to pierce the ashy blanket. Where only two or three inches of ash remained on the bog plants, they were apparently as hopelessly buried as when covered ten times as deeply. Only here and there, where the Sphagnum occupied a steep bank which was quickly cleared of ash, did it survive. The fate of such buried bog areas is one of the most interesting problems in connection with the revegetation of the country. Bog and tundra are so abundantly developed in all northern countries, that it is to be supposed that they are favored by climatic conditions, and hence their return may be expected in the Katmai district. There are not enough bog plants left, however, to reseed the areas so that in any event the general return of bog conditions must be long delayed.

HORSETAIL VERY IMPORTANT AS THE FIRST GROUND COVER.

At present the former bogs remain quite bare or are grown up with *Equisetum arvense*. In most cases the Equisetum appears to have been restricted to the edges of the bog before the eruption. In such bogs the middle remains bare ash, but the horsetail is sending long runners toward the unoccupied areas and will soon cover them. (See pictures below). While the old bogs are perhaps the most conspicuous examples around Kodiak of the ability of the horsetail to cover ground which would otherwise have remained bare, there are many other areas

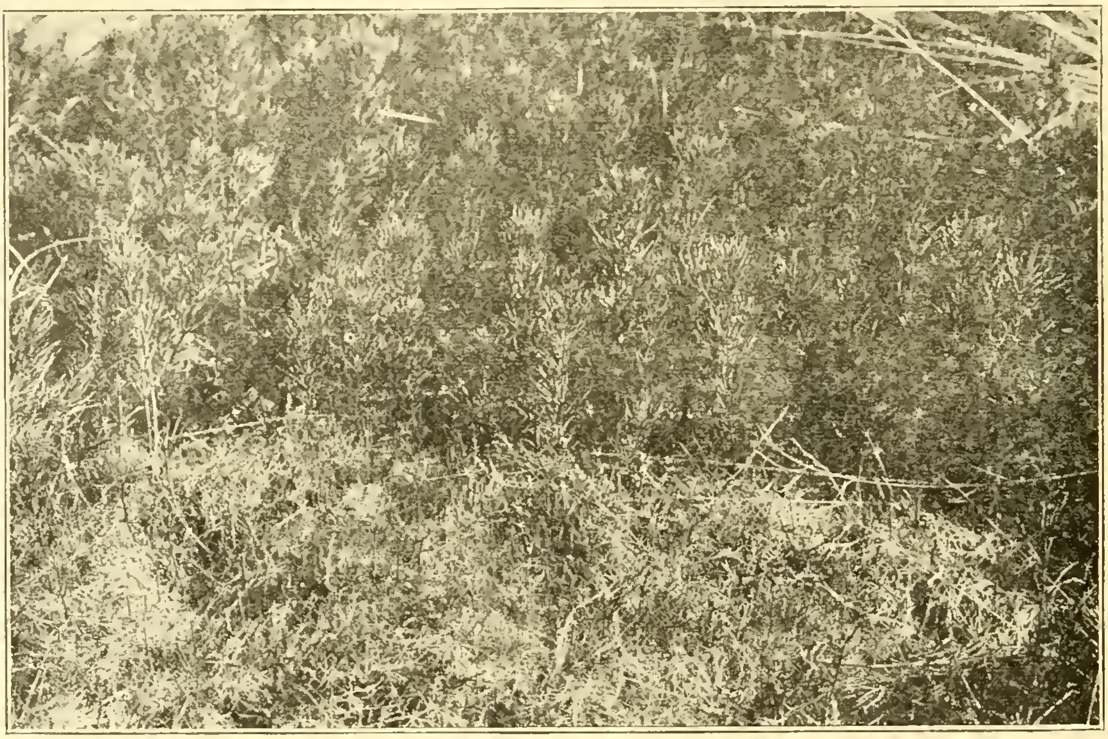
Photograph by R. F. Griggs

EQUISETUM SENDING RUNNERS INTO BARE ASH.

Equisetum has occupied large areas which otherwise would have become dunes of drifting ash. Its importance in the revegetation of the country cannot be overestimated.

where it was almost the only survival, as was brought out in an earlier paper (Griggs[2], 1915). It was by far the most important species of the flora in providing a new plant cover on the ash.

Its importance in the recovery of the country can hardly be overestimated, for over large areas it was for a long time the only ground cover. This was even more conspicuous in certain parts of the mainland than at Kodiak, for here there were literally many square miles of horsetail in pure stand. Although this cover of horsetail was of little value in itself, its service in protecting the ash surface from wind was of the greatest importance. There can be no question but that its presence greatly mitigated and shortened the period of the prevalence of the dust storms which afflicted the country after the eruption. It provided, moreover, a protection that gave very great assistance to the seedlings of other plants. Many areas now support an abundance of seedlings which would undoubtedly still be barren wastes if it had not been for the Equisetum (see cut below).



Photograph by D. B. Church

A TURF FORMED BY SEEDLINGS OF DESCHAMPSIA CÆSPITOSA.
These came up under the protection of a rank growth of the pioneer horsetail which has been cut away in the foreground to expose the grass.

HARD COMPACT BEDS OF ASH.

Returning now to the areas occupied by fine grained ash, one other set of conditions rather commonly encountered must be described. Where masses of fine terra-cotta ash are so situated as to be kept well drained, the particles "set" together so as to form a compact hard mass very unfavorable to plant growth. Laboratory experiments with this material show that seedlings grown in it are at a considerable disadvantage as compared with those in the coarser grained ash. The difficulty is probably due to lack of aeration, as well as to the mechanical obstacles to root extension offered by such a compact hard "soil." The analyses show that it is not due to any deleterious chemical in the material. Buckwheat, which was planted in an area of such ash, was red, dwarfted, and malformed, and did not advance beyond the cotyledon stage in the course of six weeks. It is not surprising, therefore, to find the areas covered by this material absolutely bare except where pierced by the old plants from beneath. (See cut below). Since the ash is composed of the most insoluble materials, there is no reason to expect a change in its physical condition. It is difficult to see, therefore, how vegetation can ever start in such areas. Some of those

Photograph by R. F. Griggs

A DRIFT OF CLOSE PACKED ASH UNSUITED FOR PLANT GROWTH. Buckwheat planted here had not passed beyond the cotyledon stage in six weeks. (Vegetation Station 14.)

chosen for vegetation stations are so located that the ash accumulation is not likely to be eroded away. Their future history will be watched with interest.

MESH-WORK OF MOSS ON THE FOREST FLOOR.

Except for the ponds, most of the habitats so far discussed belong to the open country westward from Kodiak. In the shelter of the forest to the eastward, the conditions for the growth of seedlings are much more favorable[21].

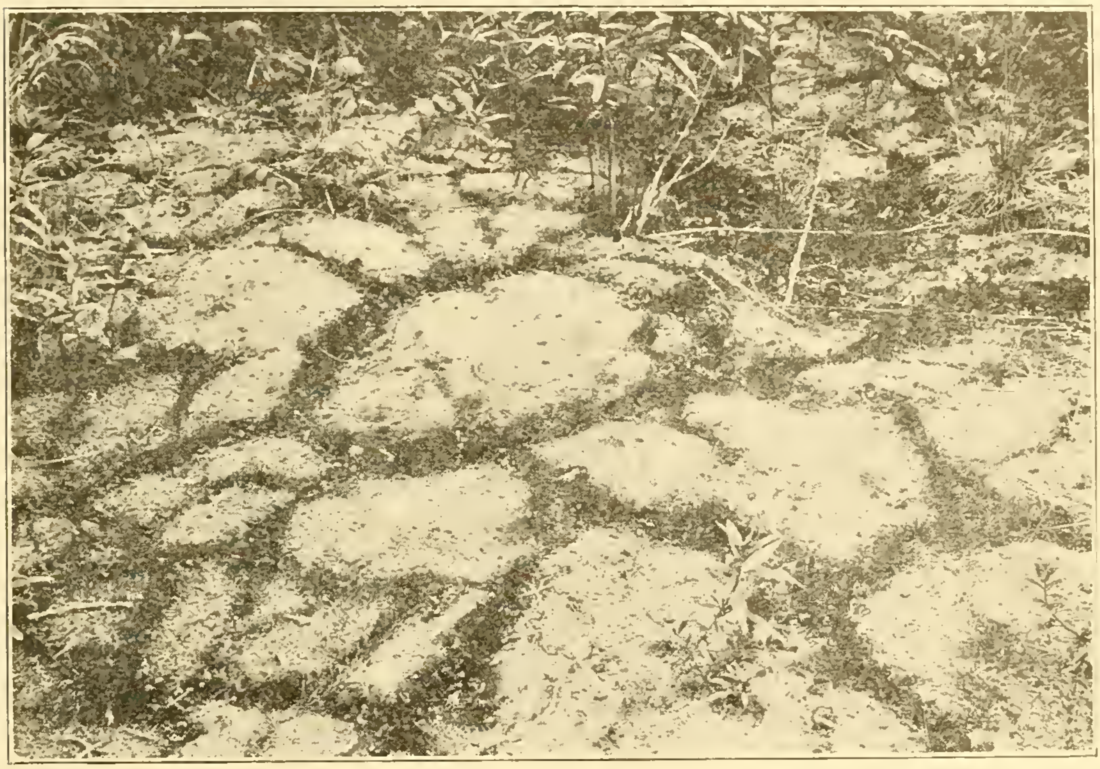
[21] Kodiak stands at the line separating the great Pacific coniferous forest from the open grassland beyond. For a discussion of the ecological aspects of this transition see: Griggs, R. F. Observations on the Edge of the Forest in the Kodiak Region of Alaska. Bull. Torr. Bot. Club. 41: 381–385. 1914.

Photograph by B. B. Fulton

MASSES OF MOSS ON THE TREES NEAR KODIAK.

These moss balls held quantities of the falling ash which have since been consolidated and bound in place by the growth of moss.

The trees themselves were but little affected by the ash fall, although their branches were heavily loaded, and in places still retain considerable ash. (See page 48). In the deeper parts of the forest the branches bore great masses of moss, which, of course, caught and held quantities of ash. During the interval that has followed the moss has grown out over the ash, making larger masses than ever and giving the trees a very bizarre appearance. (See page 46).



Photograph by B. B. Fulton

THE MESH WORK OF MOSS ON THE FOREST FLOOR.

Wind borne spores lodged in the mud cracks whose position was thus indicated by a growth of moss long after they had been filled up by drifting ash. (Vegetation Station 11).

The most striking feature of the revegetation of the forest, however, is to be found on the ground. When the ash dried out after the first heavy rains following the eruption, deep cracks appeared like the mud cracks in a dried-up puddle. (See pages 4 and 48). These cracks are, of course, long since filled up by drifting ash, but a heavy growth of moss (*Amblystegium* sp.) has come up in every crack, giving the ground a most curious reticulated appearance. (See cut above).

Photograph by George C. Martin

"MUD CRACKS" IN THE ASH AFTER THE ERUPTION AUGUST, 1912.

The cracks were 2 inches wide and 6–8 inches deep. For a long time the only plants to reappear came through such cracks. (Cf. page 47).

This curious distribution of moss is apparently due to the fact that the spores found lodgment in the cracks. The same moss often starts around fallen sticks or other objects which wind-borne spores would settle. One of the most striking instances of this was a sea-urchin shell, dropped by a raven, which was embedded in a mass of moss that had grown up around it.

SEEDLINGS OF ALL SORTS STARTING IN THE FOREST.

In the forest the trees protect the ground from the wind, and insure a stable surface on which new plants can start. It was sometime after the eruption, however, before seedlings made their appearance in any numbers even in the most protected situations. None were observed in 1913 and in the beginning of the season of 1915 they were very few and far between. But during the latter part of the season of that year, they began to appear in numbers. These seedlings included representatives of all the important members of the flora including among others: *Picea sitchensis*, *Alnus sinuata* (see page 29); *Populus candicans*, *Rubus spectabilis* (see page 30); *Calamagrostis langsdorfii* (see page 50); *Deschampsia caespitosa* (see page 44); *Archangelica officinalis*, *Heracleum lanatum*, *Echinopanax horridum*, *Lupinus nootkatensis* (see page 55); *Sanguisorba sitchensis*, *Solidago lipida*, *Agrostis hiemalis* (see pages 23 and 27); *Agrostis meleleuca* and *Chamaenerium angustifolium*, (see page 30). All of these except the last were common in many places.

The presence of large numbers of such a variety of seedlings dispelled all doubts which may have previously been entertained concerning the ability of seeds of plants to germinate in the ash. Almost without exception, moreover, they weathered the drought of the first summer, which was unusually severe for that region and were in good condition when we left the field in September. But they were not yet sufficiently abundant to be of any ecological consequence and it remained to be seen whether they could survive the winter.

SOME SEEDLINGS SURVIVED THE WINTER.

The winter of 1915-16 was extremely long and severe. The ice did not break up in the ponds until after the first of May. The minimum temperature was not very low, only +8° F., but the vegetation suffered severely. Many spruces, especially small ones, succumbed, and the canes of *Rubus spectabilis* were so severely winter-killed as to seriously diminish the crop of berries the following year. Under conditions so exceptionally severe, a high mortality was to be expected among the seedlings which, being dependent for their nutrition exclusively on roots distributed through the sterile ash, were not as well nourished and in as good condition to resist unfavorable

Photograph by D. B. Church

GRASS SEEDLINGS IN THE ASH.

Coming up under the shelter of old clumps of the same species, *Calamagrostis langsdorfii.* (Vegetation Station 44.)

influences as though they had grown in normal soil. It was found on examining them the next spring that, as was expected, the mortality had been very high. Nearly all of the special seedlings that had been marked for observation had perished. But, notwithstanding the high death rate, large numbers had survived, and the renewal of growth showed that they would be better fortified against the next winter.

Seedlings were similarly starting in sheltered places beyond the forest. Beside many a strong clump of grass, for example, the ash surface was fairly covered with small seedlings, presumably of the same species. (See page 50.) In many places beneath the omnipresent Equisetum such seedlings, especially those of *Deschampsia caespitosa*, were so thick as to form a veritable turf over the ground. (See page 44). In less sheltered situations, the seedlings often appear along the lines washed by the run-off from rains. (See cut below). A similar phe-

Photograph by D. B. Church

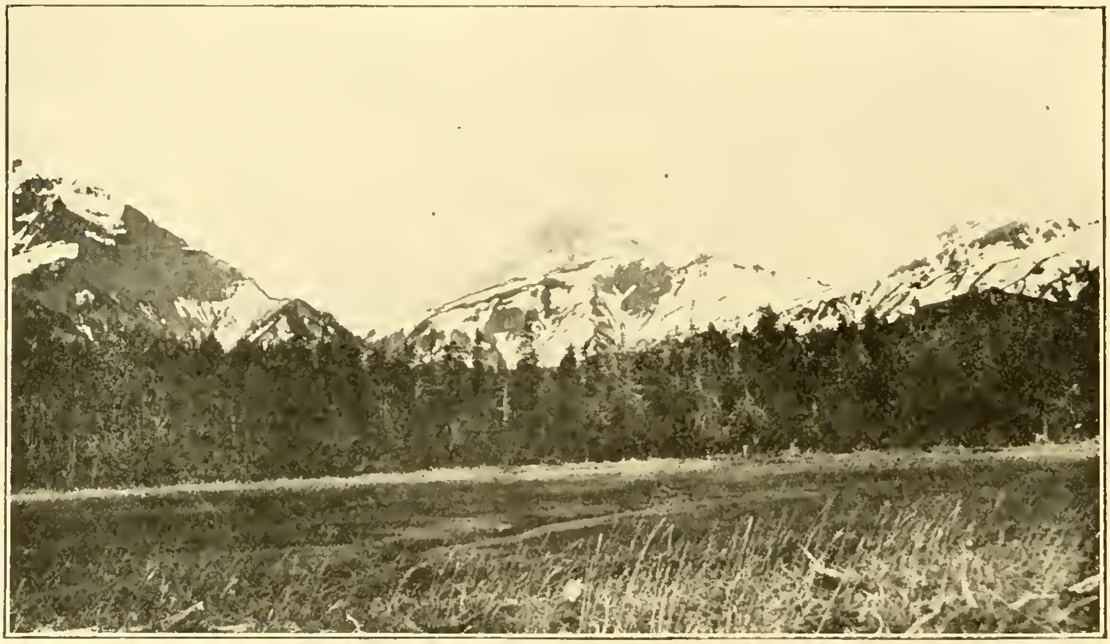
SEEDLINGS COMING UP WHERE "PLANTED" BY STORM WATER.
Polygonum aviculare and a grass. The intervening spaces where the seeds, presumably present, were not covered by washed-in sand are bare.

nomenon was observed much more conspicuously in Katmai Valley and will be discussed in detail in a succeeding paper. It is believed to be due to the fact that the running water buries the seeds beneath a layer of ash, thus preventing their blowing away and giving them a chance to start.

Beside these yearling plants were a very few others, especially of spruce and alder, which had started in earlier years and persisted. These were continuing to grow slowly. Some of them had almost succeeded in getting their roots through the ash layer and into the original soil beneath. When this connection is once made, the seedling is removed from the problem of revegetation of the ash, and the factors controlling its success or failure are the same as those affecting similar seedlings outside the ash-covered area.

SALT MARSHES RESTRICTED BUT RETURNING.

Another type of habitat, whose revegetation requires separate consideration, is the area formerly covered by salt marshes.



Photograph by R. F. Griggs

A SALT MARSH ON CHINITNA BAY.

Giving a very good idea of the general character of the salt marshes of the devastated district before the eruption.

This association throughout the southern shore of Alaska differs considerably from the more familiar salt marshes of lower latitudes in the greater simplicity of its composition. For here, instead of being a varied association including *Salicornia* and other plants conspicuously adapted structurally for a halophytic existence, the salt marsh is often composed of a pure stand of a single grass, *Puccinellia* sp. When other plants occur they are in such small numbers and so scattered that they may be considered as accidental rather than as forming definite components of the association.

The ash fall around Kodiak effectually buried the salt marsh vegetation, and the conformation of the ground is such that the ash layer does not erode away rapidly in such places, but rather has been increased by subsequent deposition. This has not only prevented the revival of the original plants, but, by raising the level of the land, has so altered conditions that considerable areas, formerly overflowed by the tide, are now above its reach. It is to be doubted, therefore, whether salt marshes will become so numerous as before the eruption.

Photograph by D. B. Church

A SALT MARSH STARTING ON AN ASH FLAT.

The plants are mostly Puccinellia amongst which may be seen numerous fragments of decaying algæ, principally Fucus. (Vegetation Station 47.)

It is only at a few places that one can look for the stages in their return. In one such place examined, numerous seedlings of *Puccinellia Alaskæ*, together with *Atriplex Alaskæ*, had started, and had reached reproductive maturity. (See cut above). But the plants stood apart from each other and had not made much progress toward the formation of the thick turf characteristic of the original salt marsh. (See page 52). No progress in this direction was shown between 1915 and 1916. But this may have been due to the severity of the intervening winter.

The ash on which the salt marsh plants were starting was foul with decaying algæ on the surface, and beneath it was blackened by bacterial action and emitted a strong odor of hydrogen sulphide. This was taken to indicate that subsoil conditions did not differ greatly from the normal salt marsh. The complete re-establishment of the salt marsh is, therefore, expected before many years have passed.

PROBLEMS OF THE FUTURE.

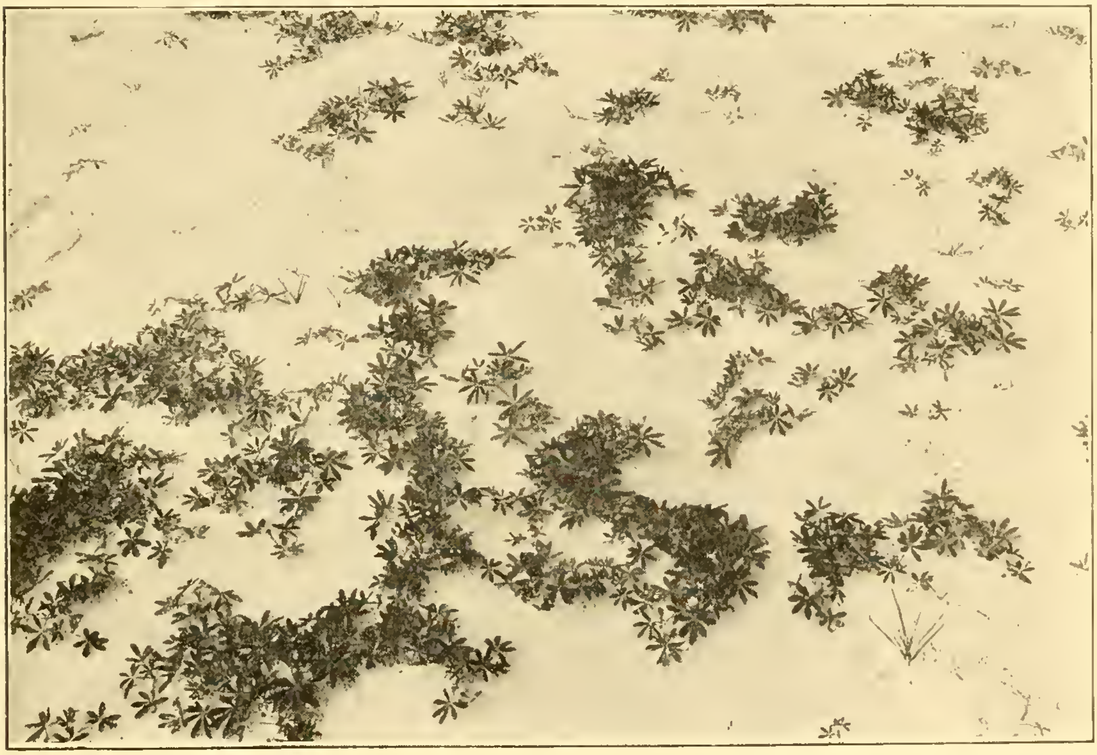
It is already clear that the recovery at Kodiak is permanent. For, with the demonstration that seedlings can start in the ash, it is evident that any gaps which may develop in the ranks of the old vegetation will be promptly filled by new plants starting from seed.

The problems of the future in this area concern, first, the fate of the exposed habitats where the surface is at present too unstable to admit of revegetation, and second, the succession of plants which will develop as the first ephemeral plant cover shall give way to more permanent vegetation, for it appears quite likely that the stages in the course of succession toward the climax associations of the country will be materially altered by the disturbance caused by the eruption.

ASH BEING RAPIDLY REMOVED.

The unstable conditions caused by the shifting sand will be, for the most part, of short duration. Where the ash layer was only a foot thick originally, it does not require a very long period for the wind to remove the whole deposit. Indeed, in many exposed places, the ash is already completely gone. And in any case it will be only a few years until the large part of the ash from the mountains has been blown out to sea. Even on the level, some places, where the wind has a clear sweep, have been nearly cleared already. Thus the field at the Frye-Bruhn ranch, repeatedly spoken of above, retains at present only enough ash to veil the black soil beneath, and the sand blast is almost a thing of the past. The conditions no longer offer any obstacle to revegetation, and in 1916 lupine seedlings came up thickly over the whole area. (See page 55). These were able to penetrate the ash and reach the old soil immediately with their roots, so that in another year the whole bare field will be green with lupine.

In places sheltered from the wind, erosion by water has proceeded so rapidly that where the land is at all steep (and Kodiak is a very rugged country), nearly all of the ash has been washed away. On the average grass-covered mountain sides, the present covering of ash amounts to only an inch or two and this is so mixed with plant stems and roots as to form a very indefinite layer. Erosion has proceeded so rapidly that even now it appears almost incredible to a stranger that the ash stood a foot deep only four years ago. I should hesitate to believe



Photograph by R. F. Griggs

LUPINE SEEDLINGS.

These have come up thickly in the plowed field shown on pages 32 and 33. They did not start until practically all the ash had blown off, just enough now remains to conceal the soil beneath.

it myself if I had not seen it with my own eyes. Within a century, volcanic ash will become almost as much of a curiosity at Kodiak as it is at other places. Long before any such period has elapsed it will be difficult to secure enough for a good specimen, except from a few special places.

Another factor, which is tending to destroy the identity of the ash as a separate layer, is the action of earthworms. The importance of these animals in ordinary soils is too well known to require mention. One frequently sees their castings at Kodiak voided on the ash surface. From the character of the castings it would appear that the worms are confining their activity to a large extent to the ash itself, but even so, their action will serve to bury increasing quantities of vegetable debris. And where they bring up the old soil from beneath, they will thoroughly mix ash and soil till the ash layer becomes hardly recognizable.

Of succession it is too early to speak or even to make predictions. Within five years, however, some indications may be expected which will give a clue to the future course of events.

ALPINE HEATH ON THE MOUNTAINS BEGINNING TO REAPPEAR.

Not directly connected with the problem in hand, but yet one of the results of the eruption, is the opportunity afforded by the devastation of the mountain tops to study the stages in the re-establishment of the alpine heath. The prostrate alpine plants occupying the summits had no capacity of sending up shoots through the ash layer, but were effectually buried beneath it. Long after the lower slopes were green with tall grass, which had come through the ash, the mountain tops remained gray wastes.

But such exposed situations were naturally the first to be cleared of ash by erosion, leaving large areas of the original surface with the soil in exactly the same condition as before the eruption. Doubtless a large proportion of the old roots remained alive as in lower altitudes, but the sand blast about the summits was so much more severe than at lower levels, that over considerable areas all of the antecedent vegetation was destroyed. These areas, therefore, give an unparalleled opportunity to study the process of the establishment of the Alpine heath, which association at Kodiak is very similar to that occupying the tops of high mountains generally.

The first stages in the revegetation of these summits have already appeared. On some of the mountains, new grasses have sprung up, apparently from seed, which almost cover the ground to the exclusion of other plants, forming in places a real turf. The most important of these are *Festuca* (*ovina*) *brachyphylla*, the vernal fascies, and *Agrostis hiemalis* var., the autumnal fascies. (See page 27). In other places, the dwarf Alpine harebell, *Campanula lasiocorpa*, has come in. Considerable areas were found in 1915 where small seedlings of this species were almost the only plants except for occasional hold-overs. The year following they had matured and were flowering in great profusion. The only other plant which at present gives promise of becoming an effective pioneer is the lupine, which, in 1916 for the first time, appeared in numbers on the mountains as well as on the lowland. There were, to be sure, other areas where a more varied flora has made its appearance, but as there was reason to suspect that these plants are survivals rather than seedlings, they will not be considered here.

It is confidently expected that, as the development of the mountain heath shall proceed, it will provide a most interesting and instructive insight into the conditions of life of the arctic-alpine flora which is a matter greatly to be desired.

If, in conclusion, we may attempt to generalize for the benefit of other countries, which might be similarly afflicted, we must recognize that the experience of Kodiak is decidedly reassuring. The damage to vegetation by an eruption is not likely to be as great as at first appears. Where the ash fall is a foot or less, no permanent injury to agricultural interests is to be expected. It would be very foolish for the people in such a region to abandon their property and go elsewhere, as some were inclined to do at Kodiak.

A PRIMITIVE TYPE OF AGELACRINITES FROM THE RICHMOND.

W. H. Shideler.

Straight rays with a rather definite trimeric arrangement are found in the very young of several species of Agelacrinites having normally curved rays in the adult stage, but are unknown in any other adult species above the Trenton.

A primitive species of this type having straight ambulacral rays with almost parallel sides and blunted ends was found in the "pebble layer" in the basal Whitewater beds of the Richmond in Adams County, Ohio, and also upon Strophomena, etc., in the top of the Liberty beds in Adams County and on Flat Fork, near Oregonia, Warren County, Ohio. The specific name rectiradiatus is proposed because of the straight condition of the rays.

In the largest specimen, 17 mm. in diameter, the rays are composed of 15 pairs of rather narrow, alternating covering plates (Plate V, Fig. 30, of the following paper by Dr. S. R. Williams), while a 6 mm. individual has 9 pairs (Plate V, Fig. 29). No other series of covering plates was seen.

The largest individual is from the basal Whitewater of Elk Run, east of Winchester, Ohio, and is in the collection of Prof. S. R. Williams. The smaller specimen is from the top of the Liberty or Cherry Fork, south of Harshaville.

Agelacrinites rectiradiatus n. sp.

Outer plates of peripheral ring two or three rows of small vertically elongate plates. Inner plates of peripheral ring two rows of quite large broad plates. Ambulacral rays (food grooves) not curved, but straight and instead of tapering down evenly, the ends of the rays are blunt and the sides nearly parallel. Each pair of lateral rays united before reaching the center, thus giving the (primitive) trimeric arrangement of the food grooves. This, together with the straight arms, produces an unusually large posterior inter-radial space. Mouth plates three, one large plate abutting the posterior inter-space, angularly emarginated anteriorly. Fitting into this emargination and obviously a continuation of the covering plates of the anterior arm a pair of anterior peristomial plates. Anus appears to consist of a single row of six angular plates. Inter-radial plates on smaller specimens much smaller and seemingly more numerous than on the larger specimens. Plates very distinctly and evenly pitted with larger depressions than those found on the plates of A. pileus. Flooring plates very delicate, probably one for each pair of cover plates.

CONCERNING THE STRUCTURE OF AGELACRINITES AND STREPTASTER, EDRIOASTEROIDEA OF THE RICHMOND AND MAYSVILLE DIVISIONS OF THE ORDOVICIAN.

Stephen R. Williams.

CONTENTS.

Introduction and Sources of Material.

The study of living animals gives many clues to the life history of closely related forms found fossil. There are, however, groups of fossil animals which have no present-day representatives and these groups are far less easy to understand.

The Cystids are a division of the Echinoderms which disappeared completely with the end of the Palaeozoic. The study of any cystid can, therefore, be aided only by distant analogies from the groups most closely related which are still in existence. Of the four divisions of the Echinoderms now extant the Crinoids are the most primitive and therefore should give most light on extinct forms.

I wish to attempt a study of one of the longest lived of the Cystids, Agelacrinites, Vanuxem. This genus is found from the Ordovician to the Carboniferous inclusive, according to Zittel, and the time of its greatest abundance is the Ordovician. The forms found in the Richmond and Maysville divisions of the Ordovician will be the only ones considered in this study.

The material worked on comes from several definite horizons. These are:

1. Several localities in the Corryville.
2. At the base and near the top of the Saluda in Franklin and Ripley Counties, Indiana.
3. In the Oakland (Elkhorn) division on Dutch and Cowan's creeks, Clinton County, Ohio.
4. At the top of the Richmond near Lawshe, Adams County, Ohio.
5. Near the top of the Richmond (Elkhorn) near Eaton, Ohio, and on Elkhorn creek, Indiana.

Additional material has been secured from collections by C. B. Dyer, of Cincinnati, and D. T. D. Dyche, of Lebanon, Ohio. These specimens are probably from the Corryville levels or below them (No. 1).

When conditions of water, its clearness and depth were satisfactory these little echinoderms were quite abundant. They lived attached to the larger shells at the bottom, clam valves being most common locations in the Richmond and the large brachiopod, Rafinesquina alternata, carrying most of the Maysville specimens. They have been found on the outer surface of a sponge, *Dystactospongia madisonensis* Foerste, on corals, *Tetradium*, on several different clams, *Ischyrodonta*, *Byssonychia*, etc., on *Hebertella*, *Platystrophia* and other large brachiopods and, notably on Cowan's Creek, in Clinton County, loose and inverted.

In this case it would seem possible (1) that the shell on which the Agelacrinites was attached was turned over by wave action and that in death the animal separated from its point of attachment and so was found lying aboral side uppermost or else (2) that the animal was not permanently attached, but could free itself and reattach.

Zittel's description of the family of the Agelacrinidæ Hall is as follows, (Vol. I, Part I, p. 187): "The calyx composed of a large number of small, irregularly arranged plates and either furnished with a short stem or fixed by a broad base. Plates pierced by pores usually united in pairs. Mouth central, anus excentric, provided with a valvate pyramid (of plates). Arms placed in radial grooves on the exterior of the calyx and protected by covering plates."

Agelacrinus: "Calyx in the form of a depressed or convex disk, stemless and attached by the entire under surface. Composed of numerous small polygonal, usually imbricating plates which are perforated by fine pores, mouth surrounded by four oral plates; radiating from this are five small, more or less curved arms which are embedded in grooves on the outer surface and are protected by a double row of covering plates."

Following Bather the recent classification puts *Agelacrinites* into the family *Edrioasteroidea*, Billings. All evidence at hand indicates that *Agelacrinites* differs from *Edrioaster* and *Lepidodiscus* in that the aboral wall contains no plates of the type which Bather calls the concentric frame plates and which may have been attached to the substratum.

The Richmond *Agelacrinitidæ* have the rays arranged in one of several ways. They are either all straight as in *A. rectiradiatus*, all turned in a counter-clockwise or contra-solar direction or else four of them are so oriented and the fifth is reversed at its outer end so as to produce one inter-radial area much larger than the others.

In this larger space, which may be called the posterior inter-radial space, are to be found the anal pyramid and an opening which is probably the opening for the water-vascular system, the hydropore.

If the specimen be so placed that the inter-radius containing the anal pyramid is toward the observer, the ray at the left is known as No. 1 and the one at the right No. 5. Food-grooves 1 and 2 are closely related to each other and food-grooves 4 and 5 are also closely related to each other. Food-groove 3, the anterior ray, pointing directly away from the anal inter-radius is separated from the right and left pairs of rays by some distance as measured on the food groove. Near the base of this ray are often found three especially large plates, the peristomial or mouth plates.

The genus *Streptaster* Hall differs from *Agelacrinites* in that it has proportionately larger and longer plates covering the food-grooves and proportionately smaller inter-radial plates. In most cases as one looks down on a specimen of this genus the ends of the palisade-like covering plates are all that is visible and no trace of the inter-ambulacral covering is evident.

Historical Review.

(Arranged in the order of description).

Agelacrinites cincinnatiensis Roemer. Described in 1851 in the Verh. Naturh. Ver. fur Rheinl, und Westphal. Vol. VIII, p. 372, Figs 3a, b.

I quote Hall's description of the fossil, 1866–72. "It has been a moderately convex disc usually with a diameter of ½ to ¾ of an inch, though it sometimes reaches a diameter of nearly one inch which is about the size of the one figured by Dr. Roemer. The disc is composed of numerous imbricating scale-like plates; the rays all curving, four sinistral and one dextral the intermediate areas composed of large plates. The mouth, anal or ovarian aperture situated subcentrally in the largest area and surrounded by a pyramid of small triangular plates.

Agelacrinus Dicksoni Billings 1858, described in the Canadian Organic Remains, Decade 3, p. 84, pl. 8. All the arms of this species are counter clockwise, the anal pyramid is described as an orifice surrounded by small plates. The type came from the Trenton limestone, Chaudiere Falls, Ottawa, Canada. Bather makes this the type of a new genus, *Lebetodiscus*. Geol. Mag. V, vol. 5, pp. 543-550, pl. 25.

Agelacrinus Billingsi Chapman 1860: No description of this fossil is attainable other than that derived from Clarke, New *Agelacrinites*, in which *A. Billingsi* from the Trenton is said to be straight armed.

Agelacrinus pileus Hall, 1866–72: "Body subglobose or globular bellshaped, attached by the smaller extremity which is composed of small squamiform plates. Rays from the top of the dome and curving gently down the sides; four sinistral and one dextral; the dextral and one sinistral surround the posterior inter-radial space. The rays are formed by two ranges of lanceolate plates, their ends pointed and interlocking over the arm grooves, their bases originating in a transverse pyramid formed by the union of two bifurcating or V-shaped plates, one on each side of the base of the anterior ray, and a single shield-shaped plate which is situated at the upper extremity of the posterior inter-radial area. The extremities of the rays appear to have been subsessile. The lateral arms are in pairs, the anterior arm being separated from them by the V-shaped plates. Inter-radial areas distinct, the posterior one quite large and composed of numerous very small plates. Ovarian (anal) aperture situated subcentrally in the largest inter-radial area."

Streptaster vorticellatus Hall, 1866–72: "All arms sinistral. Marginal portion of disc several ranges of minute squamiform plates. Inner portion of disc occupied by five elevated sinistrally curved and closely coiled rays or arm grooves, the curvature of each ray making about ¼ a volution. Rays composed of a double ray of lanceolate spatulate plates which interlock at their upper ends to cover the arm grooves. The plates forming the outer curvature of the rays are the longest and inclined at a lower angle than those of the inner side. The inner ends of the rays terminate in a solid pyramid formed by the union of the two bifurcating or V-shaped plates and one shield-shaped plate. Inter-radial areas very small, hardly perceptible. Ovarian (anal) aperture minute, situated near the bases of the postero-lateral rays."

Streptaster septembrachiatus Miller and Dyer, 1878: This seems merely an example of duplication of parts, a seven rayed specimen of the preceding species. I have a medusa which has five radial canals instead of the usual four, but it could hardly be called a new species.

Agelacrinus warrenensis James, 1883, The Palaeontologist, No. 7, p. 58, Plate II, Figs, 3, 3a. "Body circular, varying in diameter from ¼ to ½ inches or more. Attached to the convex valves of *Strophomena* (*Rafinesquina*) and probably other foreign substances. The under side concave or otherwise conforming to the surface grown upon. Disc composed of squamiform plates overlapping inward from the periphery. The plates of the outer margin very small and arranged in a narrow rim all around the narrow plates taking their place abruptly. About one line a little more inward the surface becomes suddenly depressed, causing quite a sharp outward ridge, in most cases all around, by the projecting edges of the plates and then rises, gently at first, but abruptly nearer and to the center forming a somewhat prominent dome. The rays or arms nearly hidden by the imbricating plates in all the specimens examined, but occasionally the arms are partly but indistinctly shown as is the case in the figured specimen, etc."

Dr. Foerste doubts the validity of this species and considers it merely a young *A. cincinnatiensis*. Fig. 27, Plate V, is the photograph of the type specimen of Dr. Dyche, never before published.

Agelacrinus holbrooki James: Described in the Palaeontologist in 1878 and redescribed and figured in 1887 in the Jour. Cin. Soc. Nat. Hist.

Body circular, subglobose. Disc composed of many thin plates, those in the inter-radial areas pentagonal or hexagonal, outside squamiform, imbricating; margin of disc composed of numerous small cuneiform and variously other shaped plates. Arms or rays not raised above the surface of the disc, four sinistral and one dextral ray, each composed of two rows of interlocking pieces. Ends of rays curving quite sharply upward and inward, making nearly a semicircle to near the center of the inter-radial areas and terminating in a blunt, club-shaped form.

Ovarian (anal) aperture situated subcentrally in the area between the dextral and one of the sinistral rays, depressed and composed of ten cuneiform pieces and an outer row of small thin plates placed apparently on their edges. The end of the dextral ray passes into or against the plates of the ovarian aperture."

Agelacrinus faberi Miller, 1894: One specimen only. The distinguishing character, "surface of all the plates is densely and beautifully tuberculated." The specimen according to Foerste is merely an *A. pileus* covered by an over-growth of some *Dermatostroma*.

Agelacrinus austini Foerste, 1914: "Characterized chiefly by its small size. Very moderate convexity, exposed part of the lateral covering plates ovate triangular in form, spaces between adjacent plates occupied in each case by one of the central or median series of covering plates of which a relatively greater length frequently is exposed than is the case of any other known species. Squamose inter-ambulacrals rather few. Anal pyramid, outer circle 6 ovate triangular plates, probably an inner circle of about the same. Inner band of peripheral ring one circle of large plates. Above this one circle graduating into the inter-ambulacral series, below this a third series graduating into the successively smaller plates forming the outer or marginal series of the peripheral ring. Peristomial plates believed to include corresponding to L, R and P."

Streptaster reversata Foerste, 1914: Eden shales. Characters of preceding Streptasters except that the direction of the tip of ray 5 is reversed as in *Agelacrinites*. Foerste maintains that this species is most closely related to *A. pileus* among the *Agelacrinites*.

Agelacrinites rectiradiatus Shideler. (Published with this article; see description). Figure 30, plate 5, and other figures.

Discussion of the Skeleton.

THE PERIPHERAL RING.

The rim of the disc of *Agelacrinites* is a very noticeable feature. Bounding the central radial and inter-radial spaces are a number of plates of the largest size which stand approximated in a vertical position or nearly so. Outside of these rows of large plates the plates decrease rapidly in size to the edge of the animal where they are very small.

Of what use were these two divisions in the peripheral ring? Foerste 1914, (p. 407) maintains and with reason that the outer portion was mobile and was the superficial protection of the fleshy margin, which, closely applied to the substratum, held the organism in place. He suggests that the finding specimens loose indicates that they were able to free themselves and reattach. This is paralleled among the *Holothuria* by the recent *Psolus fabricii*. "In life they attach themselves with the tightness of a chiton to the surf-beaten rocks where they live."—(From letter, H. L. Clark). A specimen collected by C. B. Dyer gives definite evidence that the outer margin was, if not actively mobile, at least adaptable under pressure. A large *A. cincinnatiensis* is attached close to a *Lichenocrinus*, the base of some small crinoid. Although *Lichenocrinus* is often found mis-shapen where conditions did not permit it to develop its circular form, this *Lichenocrinus* is essentially symmetrical and the margin of the *Agelacrinus* is deformed by it. The pressure acted on the margin of the *Agelacrinite* for some little distance beyond the *Agelacrinite* each way, indicating that the marginal skeleton was somewhat stiff rather than easily pressed inwards.

According to Foerste the inner larger plates of the peripheral ring make a rigid band. In my opinion while this band may have been rather firmly locked horizontally because the circular shape is preserved in most of the fossils, it must have been capable of some, if not great, vertical extension. The overlapping of so many rows of heavy plates (in *A. cincinnatiensis* and *Streptaster* at least) for their full vertical dimension would give a lateral support to the disc out of all proportion to the rest of the skeleton. May it not be possible that in the living cystid these plates did not overlap vertically to so great an extent as in the fossil so that the individual could be extended upward for a greater distance from the point of support. This would give more visceral space.

In a fragment of *A. cincinnatiensis* Plate II, Fig. 2, there are eleven plates side by side in this inner portion of the peripheral ring. Seven of these show at the surface and the other four are covered. The height of these plates measuring up from the substratum and beginning on the side toward the disc is as follows: 1, 1.5, 2, 1, 1.5, 1.5, 1.25, 1, .75, 1, 1, in mm. Then follow three rows of plates, the marginal zone, decreasing to about .5 mm. in height. Adding the measurements of the lower plates there is a total height of 12.5 mm. If these plates were in a membrane the contraction of circular muscles might have projected the animal out to the height of 12.5 mm. (disregarding the over-lap). This section is shown drawn with camera lucida on Plate VII, Fig. 46.

The presence of a heavy muscular wall would explain the perfect condition of the peripheral ring as well as if it (the peripheral ring) were assumed to be rigid, for the plates, if imbedded in a muscular wall, would be held in a definite position with reference to each other for some time after the death of the animal. Often the positions of the plates in the ring indicates that they have been permitted to drop gradually downward. The bottoms of the plates are found wedged together, while the tops flare outward and inward. This wedging of the plates of the inner part of the peripheral ring shows even better in specimens of the genus *Streptaster*, and *Streptaster* may have been more extensible than *Agelacrinites*.

Most of these rim plates had processes on their aboral surfaces, the larger plates as many as three processes and the smaller marginal plates one. These processes are shown in photographs 21, 22, 23 of *A. austini* var lawshe. Not all the plates are sufficiently well preserved to show such processes, but whenever conditions are favorable the processes are found.

These may be the specific points of attachment of the muscles of the muscular wall in which or on which the plates were imbedded.

COVER PLATES.

There are five "arms" on these animals, either flush with the general surface or elevated above it, depending on the species and also on the conditions of fossilization. These arms or rays are the external evidences of the food grooves, the device for obtaining more food than a simple mouth opening would be able to furnish the animal.

These food grooves are primarily trimeric in their arrangement, one extending to the left of the anal pyramid, one to the right of this pyramid and one directly away from it or in the anterior direction. All *Edrioasteroidea*, as far as I can learn, have these right and left extensions modified by dichotomous branching so that there are five rays and parts of the food groove instead of three.

Beginning with the left ray by the anal pyramid as 1, these rays are numbered clock-wise around the disc to 5 which is the reversed ray on the right of the anal pyramid except in some *Streptasters*. Number 3 is therefore the anterior ray.

In *A. cincinnatiensis*, *A. holbrooki* and *A. austini* the cover plates are arranged on each ray in two double rows while in *A. pileus*, *A. rectiradiatus* and others the cover plates seem to arch over the food groove as single pairs of plates. One can select a series of stages in the crowding of the cover plates.

Taking *A. rectiradiatus* as the simplest form, since in this species there is no complication with curving rays, we find cover plates whose free ends interlock or alternate along the midline of the groove. Diagrams of this arrangement are shown on Plate IX, Figures 54 and 56. There is usually a projection on the side of the plate nearest the mouth and the plate as seen from the side is heavy. Fig. 49, Plate VIII.

A. pileus as described by Hall and by Foerste and as far as my specimens give evidence, has but the two covering plates, one row on each side arching over the food groove.

A. austini, according to the description of the species as given by Foerste, shows besides the lateral covering plates the central or median series of covering plates, of which "a greater length frequently is exposed than in the case of any other known species." See Plate III, Figure 14, Plate VIII, Figure 50A.

In *A. cincinnatiensis* is found perhaps the greatest differences between the lateral and median rows of covering plates. Plate II, Figure 8, and Plate VIII, Figure 51A and 51B. The outer covering plates are grooved on their sides and the cylindrical median plate fills the space left by the grooving of two adjacent lateral plates. Its free end only is visible, alternating with the opposite median plate and both entirely covered from the sides by the two rows of lateral covering plates.

A weathered part of the tip end of an arm of *A. cincinnatiensis*, Plate II, Figure 11, gives the clue to these different types of arrangements of the cover plates. Only one half of the ray is left. At the distal end of the ray the plates are side by side in one series as in *A. pileus*.

As one looks proximally he finds every other plate dropping downward and toward the food groove. This is approximately the present condition in *A. austini*. Still nearer the mouth the alternate arrangement, a large lateral row of cover plates and a small median row is the normal condition that characterizes *A. cincinnatiensis*.

A young specimen of *A. cincinnatiensis*, 6 mm. in diameter, from the Corryville at Mason, Ohio, shows the primitive condition of cover plates. (Figure 29A, Plate V). The food grooves are but slightly bent. In one ray there are six plates on each side of the groove and as they have, as yet, not been crowded in the course of their development the plates are even and side by side as in *A. rectiradiatus* and *A. pileus*. It is possible that the next to the first plate at the base of the ray No. 1 is dropping inward and will take position as one of the median cover plates, producing the double row on each side, which characterizes *A. cincinnatiensis*. If so, the growing point of the food grooves is at the proximal end of the ray by intercalation of plates rather than at the distal end by addition of plates.

This crowding together of the cover plates is correlated with an increase in length of the food grooves. Again *A. rectiradiatus* furnishes the primitive straight stages. *A. austini*, Plate III, Figure 13 and 14, *A. pileus*, Plate I, Figure 3 and 4, *A. cincinnatiensis*, Plate I, Figure 2, Plate II, Figures 8 and 11, and most all *A. holbrooki*, Plate V, Figure 26, all have rays which are longer than the direct distance to the peripheral rim plates. The rays of *A. austini* at their outer ends turn slightly at the peripheral rim. *A. pileus* may parallel the rim with the tips of the rays for some distance. In *A. cincinnatiensis* the rays at their distal ends leave the rim and point back toward the center. The diagnostic character of *A. holbrooki* is that the tips of the rays return from the peripheral rim perhaps one-third of the distance toward the mouth region, dividing each inter-ambulacral region at the distal edge into two parts. I have never seen a small specimen of this form and see no reason why it may not be an exceptionally aged *A. cincinnatiensis*.

In all the species thus far mentioned the cover plates tend to be triangular or quadrangular with a spur on the proximal face of the plate between it and the next plate toward the mouth on the same side. It is difficult to identify such a spur always in the case of *A. cincinnatiensis* and I assume that it may have been merged into the flange of the groove of the outer row of cover plates and have been lost from the inner row entirely. It probably had to do with the muscular attachments of the plate.

The genus Streptaster is characterized by covering plates which are proportionately longer and more slender and which interlock in a slightly different way. One specimen from the Dyer collection shows a series of alternating small median plates as well. If the double series of plates is normal for *Streptaster* the inner row is lost to view in essentially all specimens found.

PERISTOMIAL PLATES (ORAL SIDE).

According to Zittel the characteristic number of peristomial plates is four. Foerste's diagram of *A. pileus* shows five special plates in the region of the mouth. The number of especially large peristomial plates is usually three, one large, roughly triangular with one angle toward the posterior inter-radial space and the other two angles lying along the line between the junctions of rays one, two and rays four, five, and two smaller quadrangular plates opposite the large plate. These quadrangular plates are in line with the rows of cover plates, which make the third or anterior ray.

There is a good deal of variation in these peristomial plates. Meek's figure of *A. cincinnatiensis* in the Ohio Geological Survey shows a modification of the pattern. The Dyer collection has an *A. pileus* in which the posterior plate as shown is in two parts. Figure 13, Plate III of *A. austini* shows a much more primitive condition of these plates. Another modification is shown in Figure 52 of Plate IX. Figure 54, Plate IX is the diagram of the center of a specimen of *A. rectiradiatus* from Cherry Fork, Adams County, showing the component parts of these peristomial plates as indicated by lines of fusion on plates.

The primitive condition of the peristomial region is best shown in *Streptaster*, a specimen from the Dyer collection. In most specimens of *Streptaster*, since there is a great reduction in diameter and length of the cover plates in the mouth region and since the plates over the rest of the food groove are so hypertrophied the peristomial region is rarely seen. Figure 47, Plate VIII, a diagram of the specimen mentioned, shows the small mouth plates with very little fusion into special plates. The plate marked P. shows by its grooving that it is a union of three simple plates. There is no way of distinguishing any definite anterior plates as there are three plates where one would expect the anterior peristomial plates R. and L.

The large peristomial plates described above, then, are made by fusion of a number of simple cover plates and may include the nearest inter-radials as well. This fusion often does not take place or at least does not take place completely in many cases.

PERISTOMIAL PLATES (ABORAL SIDE) AND PLATES FORMING SUBSTOMIAL CHAMBER.

The substomial chamber has been described in detail by Foerste from the Miller and Faber specimen of *A. pileus* and others. In most cases deformation of the specimen makes the aboral pattern very hard to unravel.

The material from Lawshe, which, for the purpose of this discussion, I will call *A. austini* var. Lawshe is all exposed from the aboral side and furnishes some additional information. The aboral view of the large peristomial plate P in the posterior inter-radial space has been obtained in several specimens. See Plate II, Figure 12 for plate out of its relative position. Foerste's description of it as ridged like the letter W on its surface toward the substomial cavity gives a good idea of that surface. This plate is shown rather indistinctly in Figure 44, Plate VII as two masses in the anal inter-radius. The portion of the plate toward the anal pyramid consists of a heavy ridge extending the length of the plate at right angles to the W into which the tops of the W like ridges merge. From this ridge posteriorly the plate extends toward the anal pyramid about the same distance as from the proximal part to the ridge, becoming thinner all the way until it unites with the other plate of the posterior inter-radius.

The same plate shaped somewhat differently and not differentiated at its left (aboral) end from the rest of the plates is shown in the aboral diagram of *Streptaster*, Figure 48, Plate VIII.

Foerste states that the two anterior peristomial plates are represented on the aboral side by triangular ridged plates in the Miller and Faber specimen. Figure 6, Plate I, represents a side view of an *A. pileus* which has lost its arms 1 and 5 and the posterior plate P. This same specimen is photographed from the oral side in Figure 4, Plate I. The R. and L. peristomial plates are shown edge on and as far as this specimen is concerned the plates appear thickest at the peristomial face and seem to thin out in the anterior direction.

In the best preserved of the Lawshe specimens the sub-stomial chamber is bounded definitely by the five first flooring plates with their projecting lateral processes and the posterior peristomial plate. See Figure 44, Plate VII. In other individuals this is not so plain. In one instance it appears as if a lateral process of a first flooring plate is cut off short and is connected with the lateral process of the flooring plate of the next ray by a small plate of its own width abutting directly on it.

The condition of the peristomial ring which corresponds with the Miller and Faber *A. pileus* is shown in the aboral diagram of *Streptaster*, Figure 48, Plate VIII. Here we have the first floor plates of rays 1 and 2 united closely, a plate projecting aborally between the first flooring plates of ray 2 and ray 3, a somewhat similar plate projecting between the first flooring plates of ray 3 and ray 4 and the first flooring plates of rays 4 and 5 closely united.

If we consider the oral surface again it is clear that this condition might have been expected. The oral slit is elongate from right to left, the rays 1 and 2 closely approximated at their proximal ends, the rays 4 and 5 also closely united and both sets distinctly separated from the anterior ray. In *A. austini*, at least in the variety lawshe and in the small

Agelacrinite from the Elkhorn, Figures 25 and 25A, the five rays are rather close in their origins and the aboral extensions of any plates to stiffen the peristomial ring would be less necessary. There may be sometimes a small plate in place between rays 2 and 3 and rays 3 and 4, but it is not sufficiently elongate aborally to call attention to itself, in most cases. Nor does it seem as though in the specimens at hand the R. and L. peristomial plates were far enough apart to be represented from the aboral side as these stiffening plates. I should prefer to consider these two intervening plates when present either as descendants of cover plates between the pairs of rays and anterior ray or possibly they might be the first inter-radial plates of the inter-radial areas in which they lie.

It has been shown that the posterior peristomial plate is made by the fusion of plates, the middle one of which might be considered as the apex of the anal inter-radial space. The anterior peristomial plates likewise must be made up of a fusion of cover plates, but I have no evidence that there are inter-radial plates involved. Hall calls these plates V shaped and if they are made of cover plates from ray 3 and of cover plates from between rays 2 and 4 the V shape would be the natural shape. Most that I have seen, however, are quadrangular and so there is the possibility of the incorporation of the first inter-radial plates from the respective areas.

FLOORING PLATES.

After the first flooring plates of each ray which surround the substomial chamber with the help of the posterior peristomial plate, the ray as seen from the aboral side is continued as a series of quadrangular plates, upon which the covering plates already seen from the oral side stand. These floor-plates join each other by a slightly beveled joint, the proximal end of each plate sliding slightly over the distal end of the next plate inward toward the mouth. This joint has the greatest slant or bevel in *A. cincinnatiensis* and the least, almost a vertical joint, in *A. austini* var. lawshe.

There is another beveling of these plates on the lateral (oral) surfaces in *A. cincinnatiensis.* On these lateral slanting surfaces stand the outer row of cover plates. I do not find this articular surface on those forms which have less nearly two pairs of rows of cover plates for each ray.

In *A. austini* var lawshe there are in the adults nine flooring plates after the substomial plate in each ray. Figure 41, Plate VII, shows most of these flooring plates in one ray or another. In this species there are about three pairs of cover plates for two flooring plates.

In *Streptaster* we have the primitive condition, one pair of cover plates standing on a single floor plate. This will probably hold good in the case of *A. rectiradiatus* when the flooring plates of this species are known.

In developing forms of *A. austini* var lawshe to be considered later it is quite clear that a flooring plate of the adult is made from two primitive flooring plates a proximal and a distal, fused. The crowding of the cover plates toward alternation and hence toward doubling already considered is a character which is correlated with this fusion of primitive flooring plates.

ABORAL ENDS OF COVER PLATES.

Here again the material from Lawshe gives some precise information. The condition of cover plates in Miller and Faber's specimen of *A. pileus* as described by Foerste is not common either for the specimens of *A. pileus* at hand or for *A. austini* either from Dutch Creek, Cowan's Creek or Lawshe. In the Miller and Faber specimen cover plates are described with a long basal process extending away from the ambulacral groove and under the edge of the inter-ambulacral plates.

In the Lawshe specimens the aboral end of cover plates is shown in many cases where the floor plate of the ray has slipped. The plate ends rather squarely with two enlargements one the point of articulation with the flooring plate and one more oral in position, which must have been for muscular attachment. It is this enlargement or a point just above it which must be prolonged as the basal extensions of the lateral covering plates in *A. pileus* Miller and Faber and in *A. cincinnatiensis*. A few of the plates on *A. rectiradiatus* show an extension somewhat similar to these. Might it not be that in aged specimens there was a deposit in the tissues attached to these plates so as to produce these basal extensions?

Between the enlargements on the bases of two adjoining cover plates in *A. austini* var lawshe is left a small circular opening which would connect between the radial food groove and the visceral cavity, Figure 43 A, Plate VII. These openings are shown distinctly in many of the specimens and are not accidental. They would serve as passages for podia or other tubes of an ambulacral system.

The bases of the covering plates in a specimen of *A. pileus* is shown in Figure 7, Plate I. This indicates also the very small size of the food groove (in front of the black arrow) which ran beneath the cover plates and above the row of flooring plates.

Rate of Growth.

If size can ever be considered a specific character the forms under consideration range from *A. holbrooki*, over 30 mm. in diameter, *A. cincinnatiensis*, 27 mm., *A. pileus*, 20 mm., *A. rectiradiatus*, 17 mm., *A. austini* var. lawshe, 17 mm. to *A. austini* from Dutch Creek, 10 mm. The numbers of pairs of cover plates in the ambulacral ray corresponds roughly with the diameter of the specimen.

Where the plates at the beginning of the ray were indistinct the number is preceded by an x, where indistinct at the distal end the number is followed by y. Only the outer row of cover plates was counted in any case.

TABLE.

Diameter in mm.	1	2	3	4	5	Species	Source, if not Collected
30	..	..	x38y	..	..	holbrooki	Dyche
21	x21	x23	27	24	x22	cincinnatiensis	Dyer
15	..	16y	24	23	..	pileus	Dyer
15	18y	18y	24	20	17y	pileus	Dyche
14	11y	12y	21	x19	x20y		
13	23	20	20	19y	21	cincinnatiensis	Dyer
12	20y	..	20	16	x16y	cincinnatiensis	Dyer
12	x20	x21y	12y	17y	16y		
10.5	15	13y	.15	x12y	13y		
10	20	21	20y	10y	14y	cincinnatiensis	Dyer
10	x10	17	x16	..	..		
10	18	..	15	..	..		
7.5	15	13y	15	..	13		
6	13y	..	12y	..	x15		
6	16y	15y	13y	..	..		
6	7	6	4y	x4y	5y	cincinnatiensis	almost straight rayed

These arms which were notably deficient or indistinct were omitted entirely from the count; those unnamed being *austini* or related forms.

One is often under the impression that a fossil, being ancient, must have lived a long time. This, of course, is not at all necessary. Among the numerous specimens with their aboral faces up collected at Lawshe, Figure 10, Plate IV, shows some 30 which had been seated upon a valve of Ischyrodonta ovalis(?). The largest of these is not 3 mm. in diameter and the smallest less than half that. On the same rock, Plate IV, Figure 14, is another group of five individuals which cover a similar shell nearly as fully. These range from 10 to 12 mm. in diameter. On another rock fragment I have one *Agelacrinite* approaching the larger size and several small ones about it, none over 3 mm.

There is no doubt in my mind that the specimens of 3 mm. or less attained that diameter during their first season's growth and that the ones which survived for a second season reached the larger dimension. A specimen which measures 17 mm. from this same locality may have grown for three seasons.

Dr. A. D. Mead, in the American Naturalist for January, 1900, showed that in the case of the starfish the rate of growth depends definitely on the food supply. He there gives a diagram of two starfishes of the same age (two months) the one about the size of a pinhead and the other 2.5 inches in diameter. The size also determined the sexual advancement of these starfishes and those of a certain size were mature, no matter what the length of time needed to reach that size. "We are warranted in inferring therefore that well nourished starfish arrive at sexual maturity and breed before they are a year old."

If we suppose these *Agelacrinites* were able to reproduce the second season we have evidence of a colony located at the top of the Richmond sea-deposit near Lawshe which must have had favorable conditions for at least two seasons of growth and probably three, since there are three well defined sizes represented on the clam valves. Of these the smallest specimens (up to 3 mm.) are by far the most abundant, hundreds of them being found on a single piece of rock. The size 10 to 12 mm., is rather common and the very largest, 17 mm., are represented by few individuals.

The smallest specimen identified was two-thirds of a millimeter in diameter and showed the aboral face. The smallest specimen oral side up is 1.5 mm. in diameter.

Concerning Possible Locomotion.

These animals are usually considered sessile and of course there is no direct evidence as to their locomotion. It is, however, possible that they may have been able to move and this is suggested by Clark, 1901.

The specimens of *A. austini* from Cowan's Creek are usually found unattached and aboral side up. This may be merely evidence of the loosening from the shell on which the animal had lived after its death.

The material from Lawshe shows clam valves with numerous young specimens, Fig. 20, and valves with fewer larger specimens, Fig. 24. It is possible that as valves were overcrowded some died and dropped off and the survivors occupied their space; but it is also possible that they simply moved away as they outgrew the place of attachment.

Dr. G. H. Parker has shown for gastropods that animals which show no pedal waves still may have the same type of muscular movement in a different form which will result in locomotion.

Furthermore, he finds the same type of locomotion illustrated in the *Actinians* among the *Coelenterates*, resulting in the case of *Condylactis* in an advance of more than a centimeter in three minutes.

Psolus fabricii, the recent holothurian, already referred to with reference to the peripheral rim, has a muscular "sole" which may be of much the same type as the aboral attachment of *Agelacrinites*. In spite of the distant relationship between these two forms, why may not the close parallelism between the skeletons of the two, be accompanied by the same ability to creep in the *Agelacrinites* as the *Holothurian* has?

Respiration.

It is obvious that an animal whose body is protected by so complicated a series of plates would not be able to breathe easily directly through the outer wall. The clue for the respiration is found in the related group of the crinoids. In Antedon (Parker and Haswell, Vol. 1), the rectum projects as the tubular papilla and the rectal tube is in the living animal seen to undergo frequent movements of contraction and dilation by means of which water is drawn into and expelled from the rectum. There is thus intestinal respiration.

In *Agelacrinites* the anal pyramid, which seems to be composed of either a single ring of triangular plates or this ring under-laid by a supplementary series of plates (a total of from 6 to 20 plates then, depending on the species) must have been part of a similar respiratory device. Whatever oxygenation might have taken place along the food groove, there certainly could have been a large gaseous interchange from the rectal water content through its walls to the coelomic fluid and thus to all structures in the body. Figure 2, Plate I, Figures 15, 18 and 19 of Plate III, Figure 29, Plate V, Figures 22 and 23 of Plate IV, Figure 33 of Plate V, show the plates of this pyramid. Figure 41 of Plate VII, and Figure 52 of Plate IX, are diagrams of the pyramid as seen from the aboral side.

The starfish is said to have plates in the walls of the stone canal and it is possible that these plates may be related in a similar way to the mechanism for keeping the ambulacral system of the starfish full of water.

Water System.

Not much information on this subject is furnished by the specimens at hand. In one specimen from the Dyer collection, Figure 2, Plate I, there are two plates in the ink circle in the posterior inter-radial space by the proximal end of arm 5 which appear as a duct had passed between them.

A specimen marked *A. pileus* in the Geological Museum of the Ohio State University shows a plate in this same region which has a distinct pit or pore in it.

Another specimen of *A. pileus* seen has this same plate, but instead of a pore there is a notch on the edge of the plate next the inter-radial space.

According to Bather this is the location of the hydropore, or one of the hydropores, which correspond to the madreporic body in the starfish. He suggests that there may be as many as five hydropores present, but I have been able to find traces of this one only.

Two specimens showing the aboral side from the Elkhorn demonstrate corresponding pits next to ray 5 on the left side of the substomial chamber in the inter-radial area which contains the anal pyramid. The pit gives little evidence as to the direction the water tube took. From the presence of the circular openings between the cover plates on each side of a ray one would assume a ring canal just outside the bases of the substomial chamber plates and a double radial water tube, one on each side of the ray. Figure 25 and 25A, Plate IV.

Stages in Development (aboral side).

The specimens from Lawshe were from 17 mm. down to two-thirds of a mm. in diameter, as stated above. Only a very few of them showed the oral side.

In the section on the rate of growth attention was called to the great numbers of specimens which were found on single clam valves. The usual size of these abundant specimens is 2 mm. in diameter and less. From these specimens showing the aboral face a series has been selected to show the increase in flooring plates.

The first one, Figure 38, Plate VII, 1.3 mm. in diameter shows the ring of first flooring plates which make the boundary of the substomial chamber. In this specimen the anal pyramid was not to be distinguished and the arms are not numbered. Figures 39, 40 and 42, showing 2, 3, and 4 flooring plates respectively, are drawn to the same magnification as Figure 29 and the arms are marked with the numerals they would have if the specimens were oral side up. The anal inter-space is marked with the letter A.

Only the first and fourth of these diagrams attempt to show all the plates of the aboral side. The specimens are so delicate and the plates so easily disarranged in death and fossilization that it is exceptional in these small-sized specimens to find a pattern that can be worked out completely.

Specimens 1.3 mm. in diameter from the oral side—Plate VI, Figure 35, shows a group of small animals from the oral side. Several of these are indicated by circles for easier recognition. Figure 55, Plate IX, is a diagram of the plates of a number of specimens. Figure 37, Plate VI is one of the three outlined in Figure 35, but photographed with a higher magnification. The broad white arrow is pointing toward the anal pyramid, which may consist of four or six plates. The rest of the disc inside the rim is not clear, but is made up of comparatively few plates. Without doubt this animal has but one row of floor plates and if seen from the aboral side would be like Figure 38, Plate VII. There are just two rows of plates in the peripheral rim. I cannot differentiate radial and inter-radial plates in these small specimens. Since, as I have shown above, there is a possibility of a fusion of cover plates to form the peristomial plates of the adult, there may not yet be represented more than enough plates to make these and the differentiation into radial and inter-radial plates may first occur at a larger size.

By the time an individual developed its second (adult) floor plate in each arm, the one outside of the five bounding the substomial chamber, it should have two or three pairs of small cover plates to indicate each arm on the oral side and the inter-radial plates should be distinguishable. Such an animal should be 2.5 mm. in diameter and none of this size were found with the oral side exposed.

Alimentary Canal.

These very young specimens from the aboral side show plainly what I take to be the path of the alimentary canal. The skeletal plates are delicate, the animal a rapidly growing one and it would be more likely that an animal killed with the intestine dilated with food would have the position of the skeleton modified by this intestine than that of a similar full intestine would change the shape of the skeleton of an adult.

Attention was called to this matter by finding numerous cases of a seeming break in the skeletons of these small creatures as seen from the aboral side. There is a depression extending around the substomial chamber and just within the peripheral ring. This depression begins at the posterior part of the substomial chamber and is continuous with its cavity just at the point where the aboral part of plate P will be in the adult. It extends around just outside the first (and only) floor plates from the anal inter-radial space back to this same interspace again. The alimentary canal would occupy just such a position if it passed posteriorly out of the substomial chamber and made a complete circle around in the body cavity between the peripheral rim and the ring of the first floor plates, to connect with the anal pyramid in the posterior inter-space. Plate VI, Figures 32 and 34 are photographs of two specimens showing what I have just attempted to describe. There is no way of deciding in these specimens whether the alimentary canal, after leaving the substomial chamber posteriorly, twisted to the right or to the left. Both photographs show the depression, constricted at each floor plate and expanded between floor plates around the whole central ring. If one were to make a guess, the intestine may have turned in a counter-clockwise direction (oral orientation) to the left in each photograph and with four inter-ambulacral enlargements may have reached the anal pyramid at a point very close to where the intestine left the posterior inter-radial space.

Summary and Conclusions.

1. Agelacrinites was probably somewhat motile, at least able to adapt its skeleton to its surroundings.

2. The peripheral rim may have been extensible.

a. Evidence from the downward dropping of the inner rim plates.

b. The great redundancy of the large plates in some of the species for simple support.

c. Processes, probably for muscle attachment, on the aboral side of the most of the rim plates.

3. The animals in the Lawshe colony were probably sexually mature the second season (by analogy from the star fish).

4. They breathed by muscular protraction, extension and retraction of the anal pyramid, getting oxygen by rectal respiration.

5. The cover plates are variable in their arrangement, the primitive condition being a single row on either side of the brachial groove and the most complex a double row, an outer large row and alternating with these an inner, small row on either side of the arm. Transitions between these two conditions are shown.

6. There is a hydropore in the posterior inter radius near the posterior peristomial plate and near arm 5.

7. There are passages between the bases of the cover plates at their aboral ends which probably have to do with a water-vascular system.

8. The peristomial plates are derived from the primitive cover plates, and in the case of the posterior peristomial plate at least also from the primitive inter-ambulacral plates by a greater or less amount of fusion. Streptaster furnishes the most primitive condition of peristome.

9. The substomial chamber is made by five specialized flooring plates and the posterior peristomial plate mentioned above. Some species may have two additional plates, one on either side of the anterior first flooring plate.

10. Cover plates one pair to a floor plate to nearly two pairs (outer) to a floor plate. In the latter case the flooring plate is two primitive floor plates fused.

11. Stages with one, two and three floor plates are shown.

12. The probable path of the alimentary canal in the small animal is shown.

I wish to thank Mr. W. McCord, of Cincinnati, for the privilege of studying his specimens of *Agelacrinites*. Also Dr. H. L. Clark, of the Museum of Comparative Zoology, Cambridge, Mass., for specimens of the recent *Holothurian Psolus fabricii* from Grand Manan. Also Dr. W. H. Shideler, for the use of his material.

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DESCRIPTION OF PLATES.

PLATE I.

Fig. 1. Specimens of *Agelacrinites* attached to *Dystactospongia Madisoniensis*. Coll. W. H. Shideler, Fallen Timbers Creek, Indiana. X. I.

Fig. 2. *Agelacrinites cincinnatiensis* showing the effect on the peripheral rim of crowding against a *Lichenocrinus*. Dyer coll. × 3.
Also shows the hydropore (?) between two plates near arm 5.

Fig. 3. *Agelacrinites pileus* to show the outer smaller plates of the peripheral rim. × 4.

Fig. 4. *Agelacrinites pileus* with peristomial Plates L and R in position and P dropped out. Seen from above. × 4.

Fig. 5. An *Agelacrinite* having long cover plates like those of *Streptaster*. Possibly is *Streptaster*.

Fig. 6. Edge view of the same *A. pileus* photographed in Fig 4., showing the thickness of the median edges of the special peristomial Plates L. & R. × 4.

Fig. 7. Aboral side of an *Agelacrinites pileus* with flooring plates dropped out and with the arrow indicating the narrow food groove on the aboral side of the cover plates of one arm. × 4.

PLATE II.

Fig. 8. *Agelacrinites cincinnatiensis* showing the cover plates of the outer and inner series for almost the whole extent of their length on a part of food groove 1 as cleaned. Dyer coll. × 2.5.

Fig. 9. *Agelacrinites cincinnatiensis* showing food grooves 2 and 3 with the peristomial region. McCord Coll. × 2.5.

Fig. 10. *Agelacrinites pileus* showing the single cover plates of the food grooves and the inter radial plates. Dyer Coll. × 3.

Fig. 11. Fragment of *A. cincinnatiensis* showing especially the numerous rows of large plates in the inner part of the peripheral rim, and the cover plates of one side of the distal end of a food groove. W. H. Shideler Coll. × 3.

Fig. 12. Aboral views of two specimens of *Agelacrinites austini var lawshe*. Upper specimen shows the detailed aboral view of the posterior peristomial plate.
Lower showing in part peristomial chamber and the oral view of a flooring plate of a food groove. × 3.

PLATE III.

Fig. 13. Camera diagram oral view of all plates (disc, peripheral ring, margin) of a specimen of *Agelacrinites austini* (Foerste) from Dutch Creek. W. H. Shideler Coll. Anal pyramid plates put in from another specimen. × 5.

Fig. 14. Photograph of specimen diagrammed in Fig. 13. × 4.

Fig. 15. *Agelacrinites* to show anal pyramid. Dyer Coll. × 4.

Fig. 16. Camera diagram of aboral view of all plates of a specimen of *Agelacrinites austini* from Cowan's Creek. × 5.

Fig. 17. Photograph of specimen diagrammed in Fig. 13. × 4.

Fig. 18. *Agelacrinites pileus* showing anal pyramid with plates separated, leaving a rectal space. McCord Coll. × 4.

Fig. 19. Possibly *Streptaster reversata* Foerste. Shows peristomial plates and anal pyramid closed. McCord Coll. × 4.

PLATE IV.

Fig. 20. Group of young *agelacrinites austini* var. lawshe, from Lawshe, Adams County. Seen from the aboral side. On valve of *Ischyrodonta ovalis* (?). × 4.

Fig. 21. *Agelacrinites austini*, var. lawshe, to show the vertical ridges on the aboral side of many plates, especially those of the peripheral ring. × 3.

Fig. 22. *Agelacrinites austini*, var. lawshe. To show the floor plates of most of the food-grooves and the substomial chamber. Aboral side. × 3.

Fig. 23. *Agelacrinites austini*, var. lawshe. Aboral view of one of the largest specimens found. Shows one of the modified first flooring plates bounding the substomial chamber with its lateral projections.

Fig. 24. Group of older *Agelacrinites austini*, var. lawshe on Ischyrodonta. × two-thirds. As compared to Fig. 20 five specimens occupy a shell similar to the shell with over 30 specimens in Fig. 20.

Fig. 25. *Agelacrinites* from Eaton (Elkhorn) showing substomial chamber, anal pyramid and hydropore (indicated by arrow). × 4.

Fig. 25A. *Agelacrinites* from Elkhorn Creek showing substomial chamber, hydropore and a food-groove, No. 4, which has lost its flooring plates. The path of the groove is indicated by crosses. × 4.

PLATE V.

Fig. 26. *Agelacrinites holbrooki* from the Dyche collection showing the character of the re-entrant rays. × 2.

Fig. 27. *Agelacrinites warrenensis*. Photograph of the type specimen from the Dyche collection published now for the first time. According to Foerste a young *A. cincinnatiensis*. × 4.

Fig. 28. Fragments of a specimen of *Agelacrinites rectiradiatus* Shideler showing a few cover plates. The reticulate condition of two rim plates. From Grace's Run, Adams County. Coll. W. H. Shideler. × 3.5.

Fig. 29. *Agelacrinites rectiradiatus*, perfect small specimen from Cherry Creek, Adams County. Coll. W. H. Shideler. × 4.

Fig. 29A. *Agelacrinites cincinnatiensis*, perfect young specimen with nearly straight rays.

Fig. 30. *Agelacrinites rectiradiatus*, larger specimen showing the characters of the species. Elk Run, Adams County. × 3.

Fig. 31. *Streptaster vorticellatus* from oral and aboral sides. Dyer collection. The substomial chamber is shown near the bottom of the specimen seen from the aboral side, which is the lower of the two. The specimen showing the oral side is unusually perfect showing interradial plates, marginal plates and the peripheral ring plates at the upper side. × 2.5.

PLATE VI.

Fig. 32. *Agelacrinites austini* var. lawshe, aboral view of very small specimen. Showing the five first flooring plates, the substomial cavity formed by them and the circular depression or groove outside of the first flooring plates. × 40.

Fig. 34. Another specimen showing the same points as Fig. 32. × 30.

Fig. 33. A specimen, aboral view with three flooring plates under each food groove. The outlines of the flooring plates have been dotted in on the photograph. × 8.

Fig. 35. A group of small specimens from the oral side. Some of the best preserved ones outlined in ink. These probably have no permanent cover plates except what will go into the peristomial plates and only one flooring plate in each food groove. × 4.

Fig. 36. A specimen, aboral view like Fig. 33 but with four flooring plates under each food groove. × 6.

Fig. 37. One of the specimens from the oral side seen in Fig. 35 magnified 40 times. The anal pyramid of about six plates is shown and a few disc plates. There are no specific cover plates for the grooves. Food grooves four and five seem to be separating at the right. There is one row of peripheral ring plates, one row of marginal plates.

Plate VII.

(All figures are camera drawings and are × 8.)

Fig. 38. *Agelacrinites austini* var. lawshe, minute form aboral view. All the plates distinguishable on the aboral side are outlined. The substomial chamber and peristomial ring of modified floor plates are distinct. No other flooring plates are separable.

Fig. 39. *Agelacrinites austini* var. lawshe, aboral view showing substomial chamber, peristomial flooring plates and one additional flooring plate of food grooves 1, 2 and 5. The location of the anal pyramid is indistinctly indicated.

Fig. 40. *Agelacrintes austini*, var. lawshe, aboral view. This shows food grooves with two flooring plates in addition to the peristomial ring of modified plates. The plate next the modified flooring plate on both food grooves 1 and 2 shows it double origin by a groove dividing it into proximal and distal halves.

Fig. 41. *Agelacrinites austini*, var. lawshe, aboral view medium sized specimen, all plates drawn which were distinguishable. The peristomial ring is shown open toward the anal pyramid, and with a triangular plate which is the downward projection of oral plate P, and under several of the flooring plates in food groove 1, the location is indicated of the round pores which lead to the oral side of the plate and therefore to the food groove.

Fig. 42. *Agelacrinites austini*, var. lawshe, aboral view. Specimen shows all plates distinguishable. There are three flooring plates shown in the food grooves 1 and 5, while the others are less complete.

Fig. 43. View of the flooring plates and slipped over bases of the covering plates of one food groove of a specimen of *A. austini* var. lawshe, showing the grooves between the covering plates leading out of visceral space.

Fig. 43. *A* is a similar view of a small portion of another food groove.

Fig. 44. The substomial chamber and beginning of food grooves in another specimen of *A. austini* var. lawshe. The aboral projection of plate P is distinct and also an unmarked plate at the end of groove 5 which may be the peristomial plate V displaced.

Fig. 45. Oral view of the food grooves and plates of a specimen of *A. pileus*, showing the trimeric arrangement of food grooves disguised by the separation of 1 and 2 and of 4 and 5.

Fig. 46. A section through the plates of the "rim" of *A. cincinnatiensis* to show the great number of these plates and the way they have dropped together.

Plate VIII.

Fig. 47. Oral view of *Streptaster vorticellatus* showing the peristomial plates, cover plates and a few of the minute inter radials in inter space 4–5.

Fig. 48. Aboral view of *Streptaster*, showing the substomial chamber region and a large mass not separable into plates in the region of the 1–5 inter-radial space in which the anal pyramid is located.

Fig. 49. Two cover plates of *A. rectiradiatus*.

Fig. 50. Oral and end views of a flooring plate of *A. austini* var. lawshe.

Fig. 50A. Oral view of food grooves of *A. austini*, showing the alternation of large and small covering plates.

Fig. 51. Oral view of two floor plates of *A. cincinnatiensis*.

Fig. 51A. Oral view of food grooves of *A. cincinnatiensis*, showing the covering of all but the ends of the inner smaller row of cover plates by the outer larger plates.

Fig. 51B. End view of open food groove showing the inner covering plates dotted in position. Also end view of one large covering plate showing one small plate and the groove in which it lies.

Plate IX.

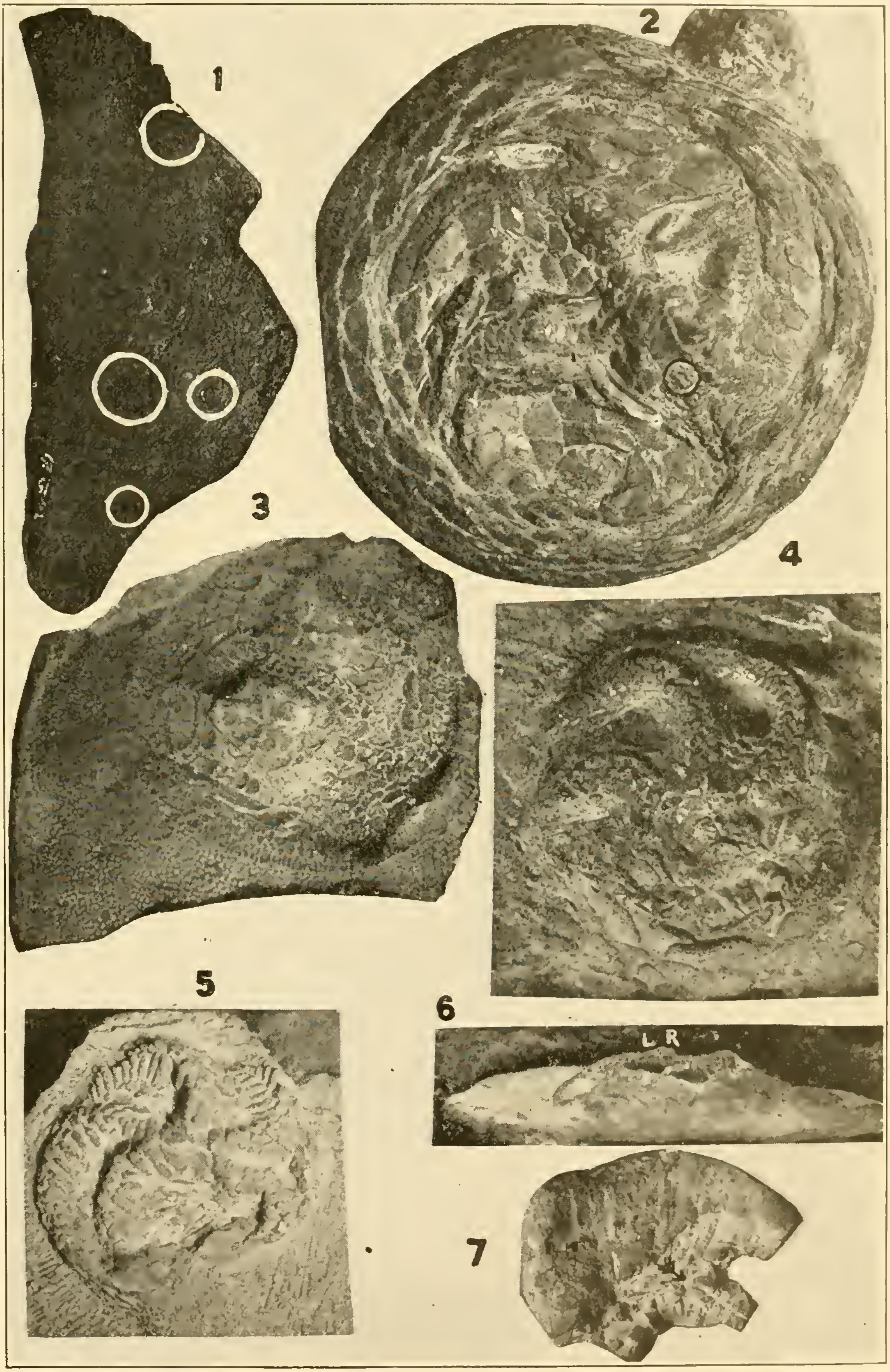
Fig. 52. Outline of oral plates and food grooves of *A. austini*, showing the union of grooves 1 and 2, and that of grooves 4 and 5 into the primitive trimeric arrangement. The large plates of the anal pyramid are 7 in number. Oral plates not united into the usual three.

Fig. 53. Oral plates and food grooves of a specimen of *A. pileus* showing elements of Plate P.

Fig. 54. Oral plates and food grooves of *A. rectiradiatus*, Shideler, diagram from small specimen. Fig. 29, Pl. V. The dotted lines indicate the probable number of plates forming the oral plates.

Fig. 55. Several diagrams of plate systems of oral side of minute specimens of *A. austini* var lawshe.

Fig. 56. Oral plates and rays 4 and 5 as shown in large specimen of *A. rectiradiatus*. Small arrow shows probable location of hydropore.



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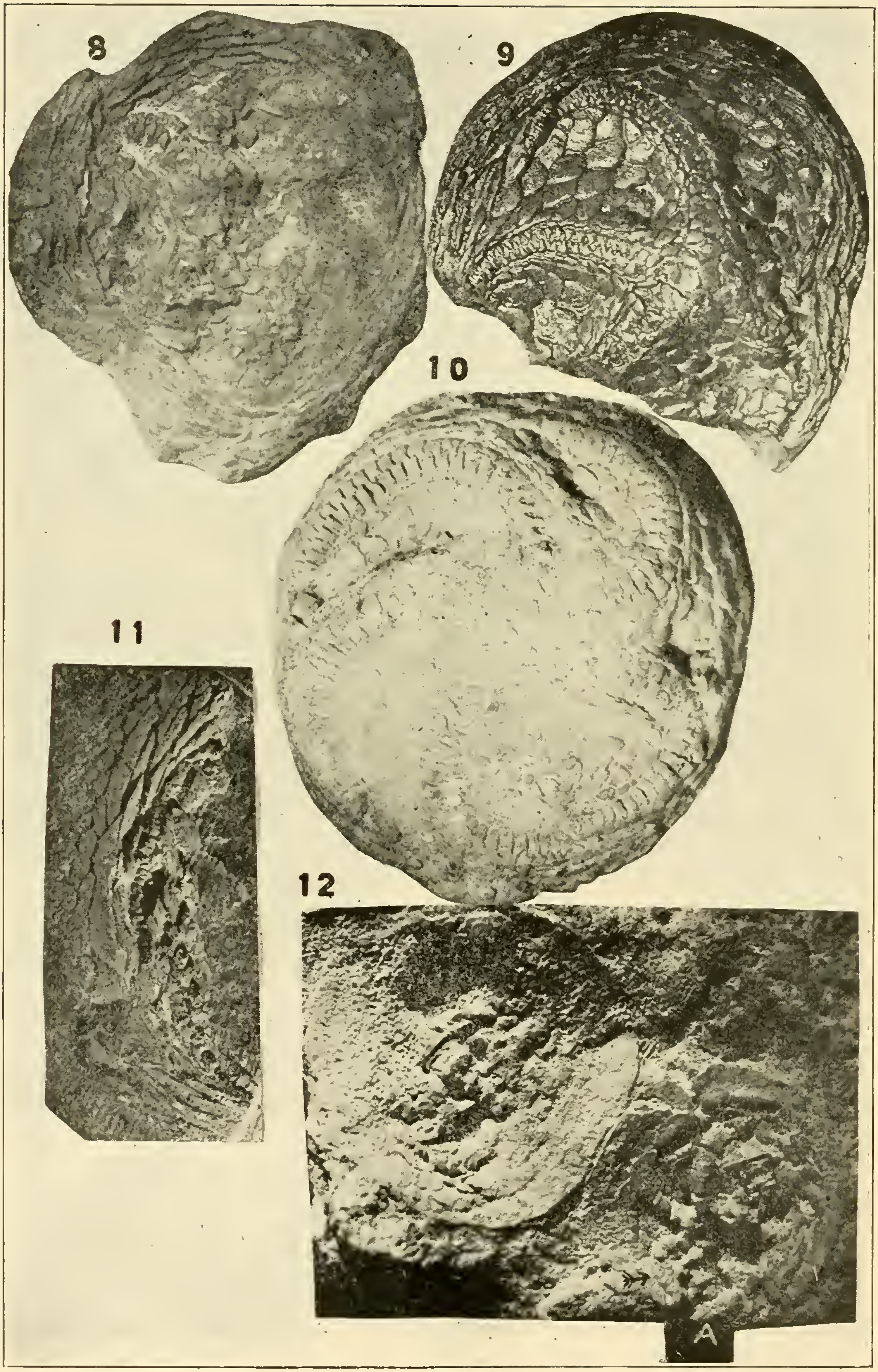

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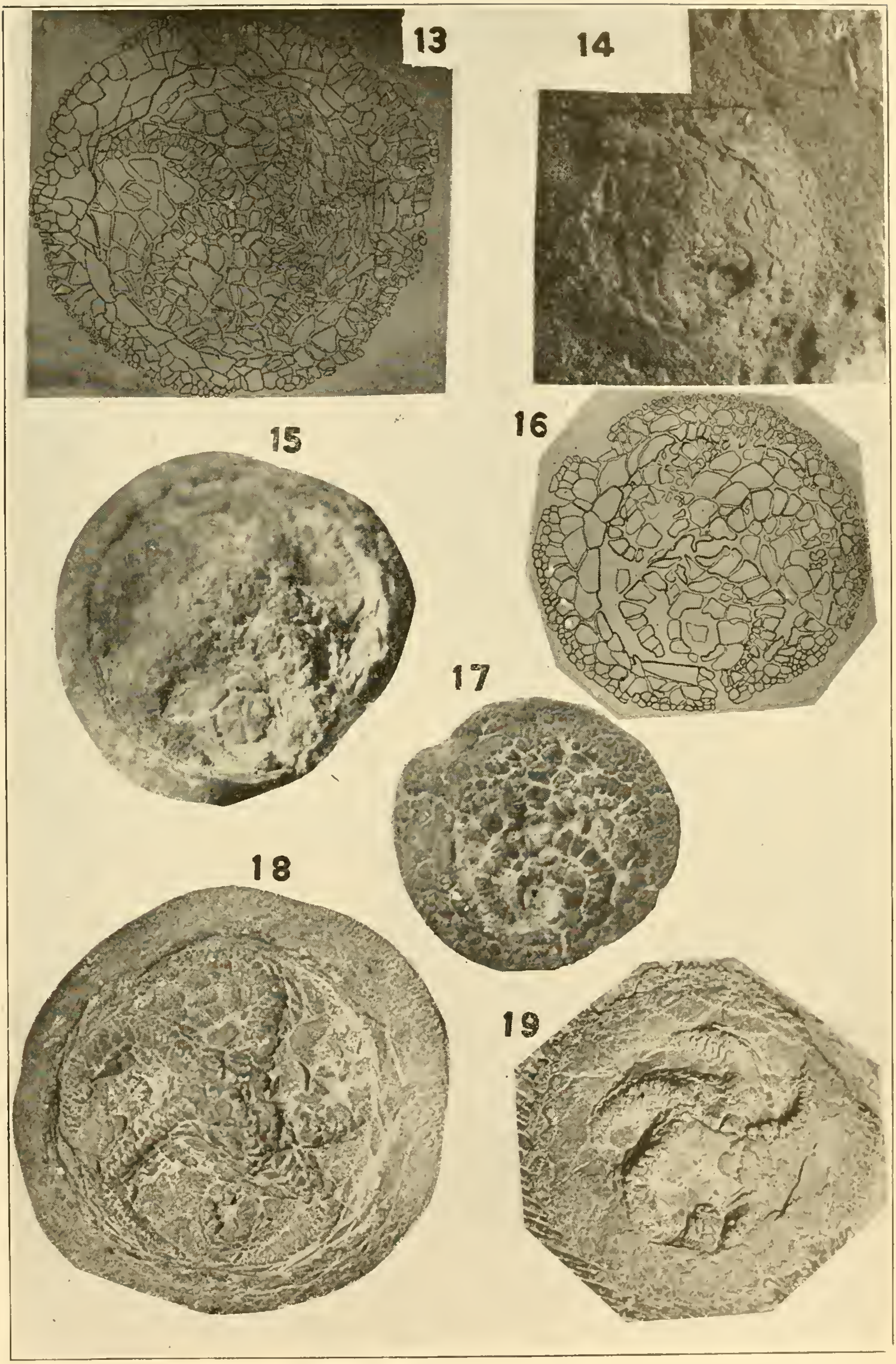

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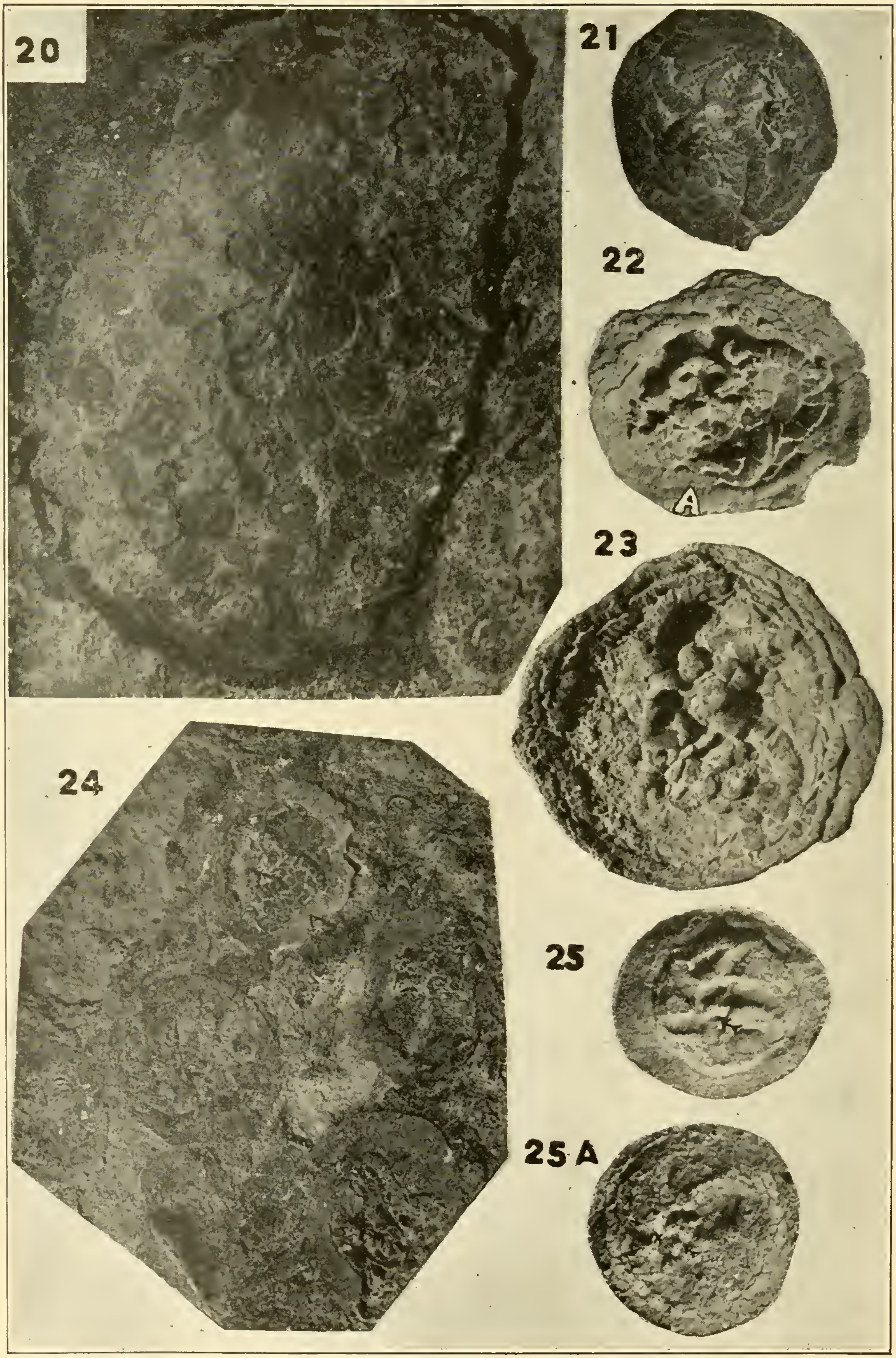

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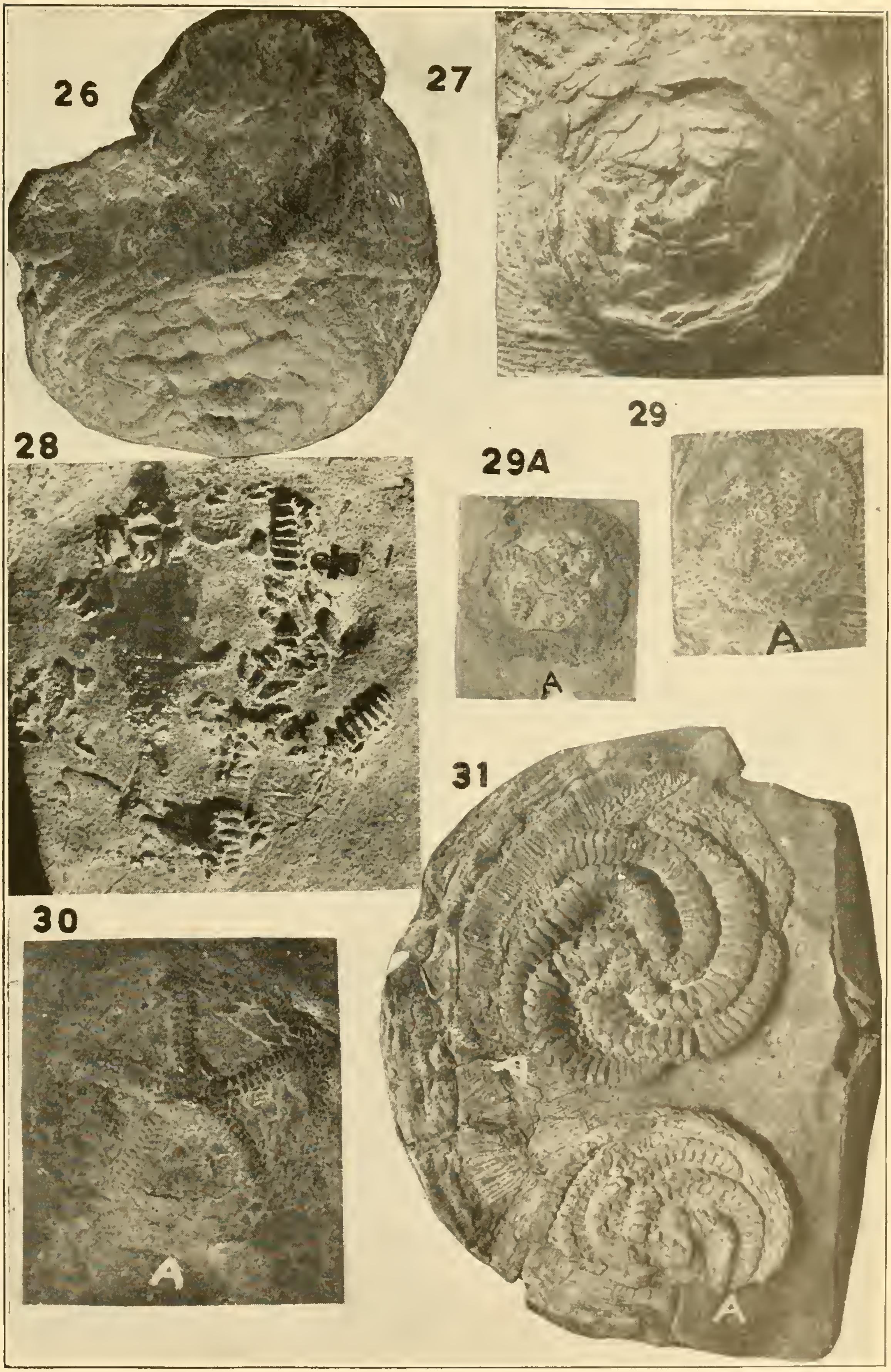

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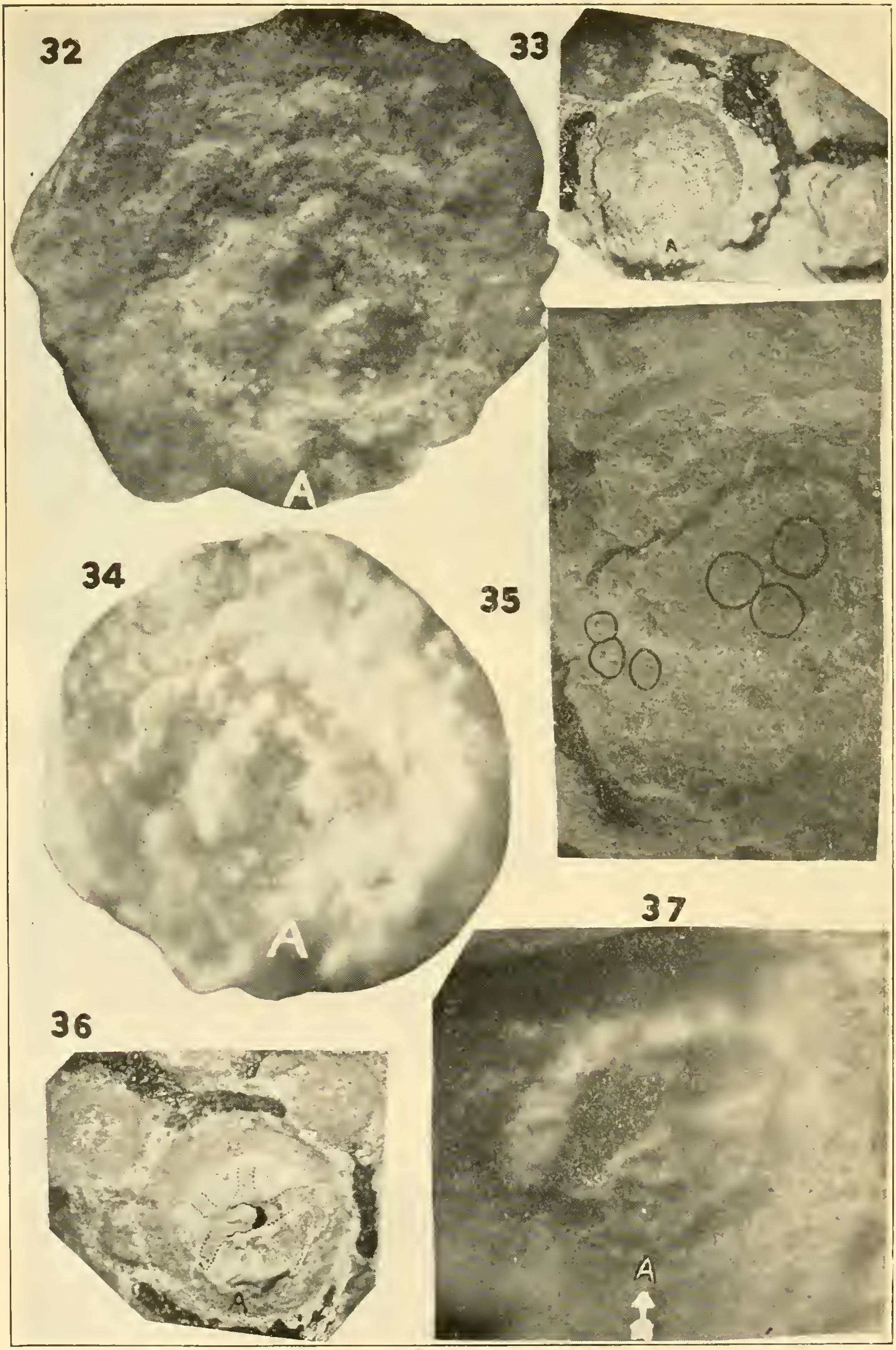

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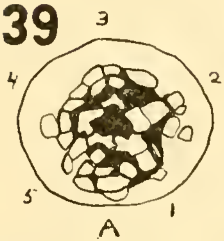

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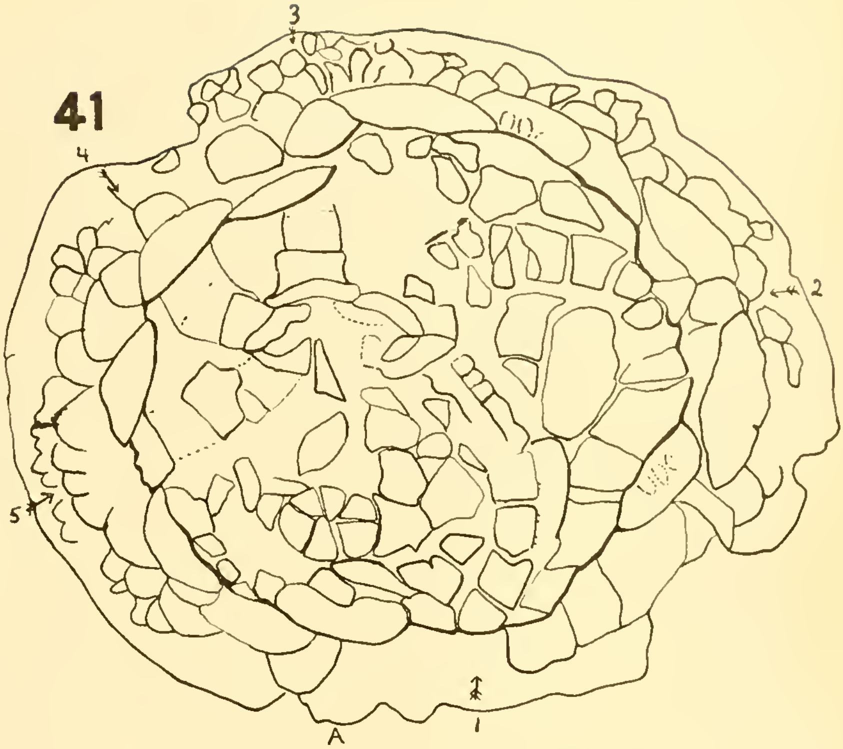

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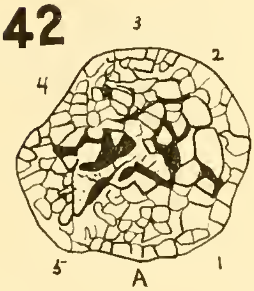

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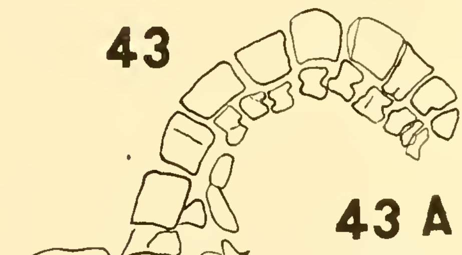

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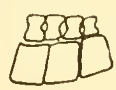

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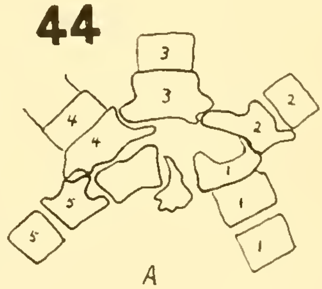

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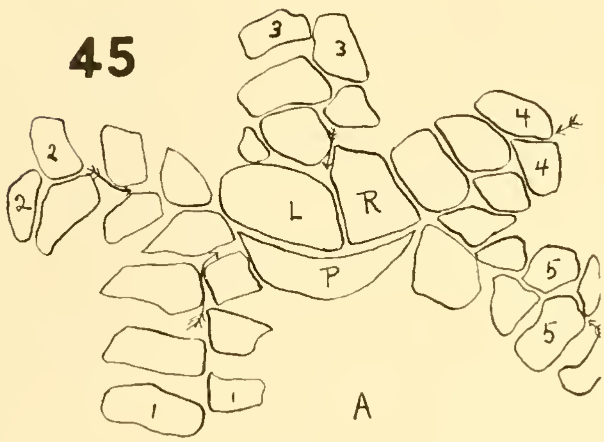

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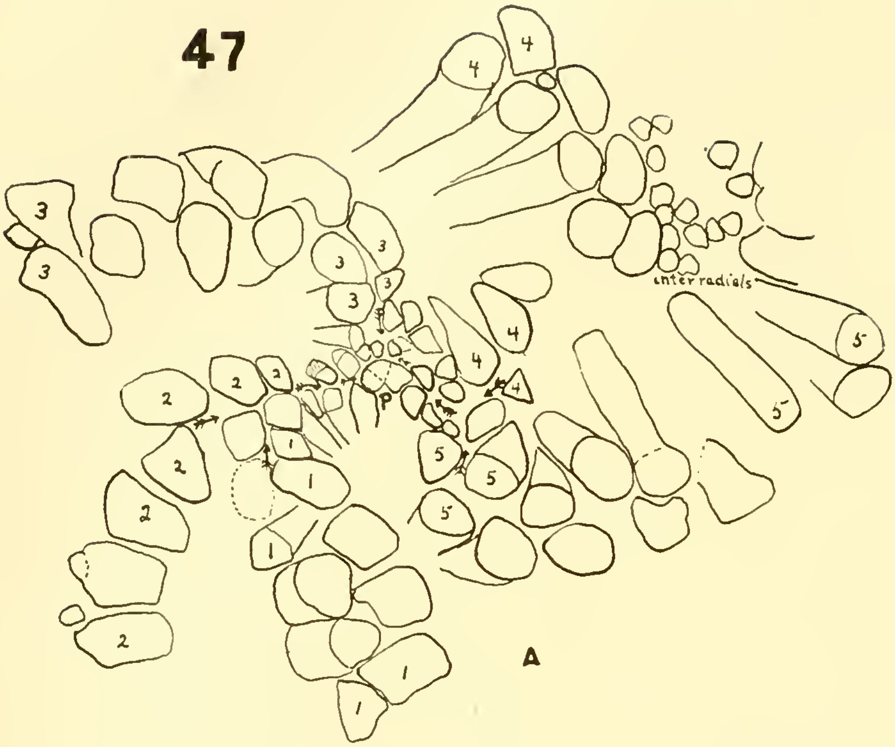

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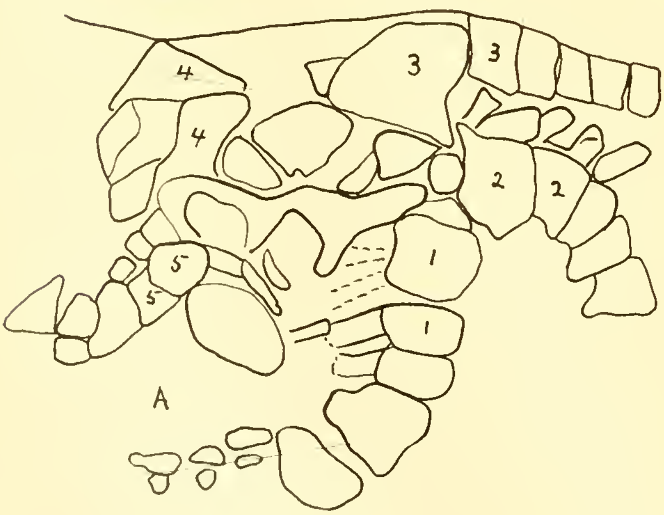

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50 A

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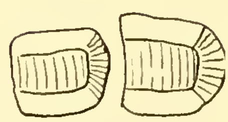

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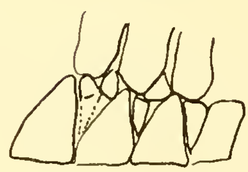

51 B

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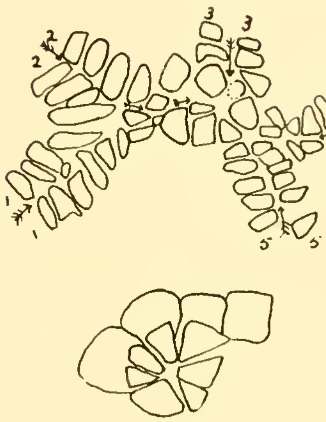

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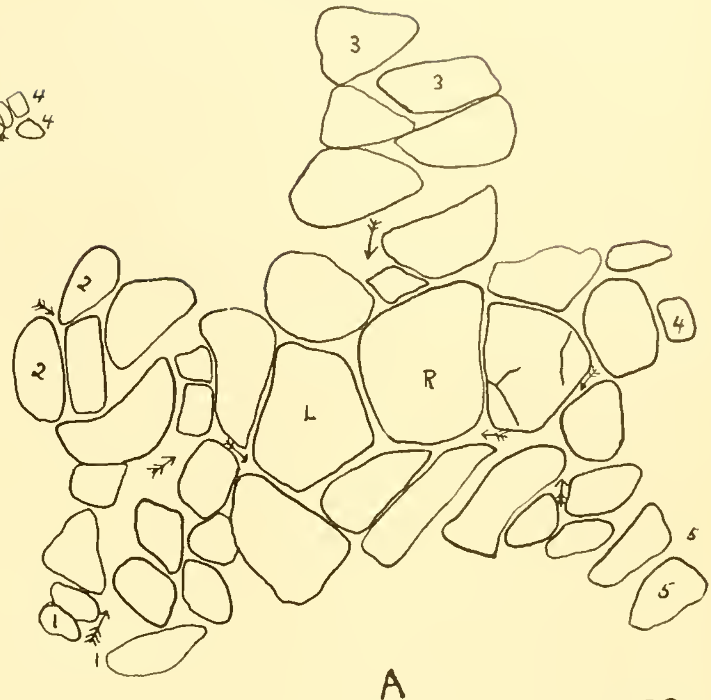

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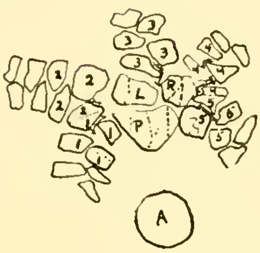

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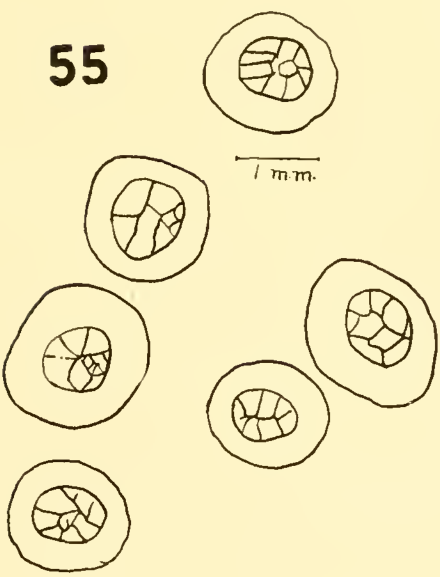

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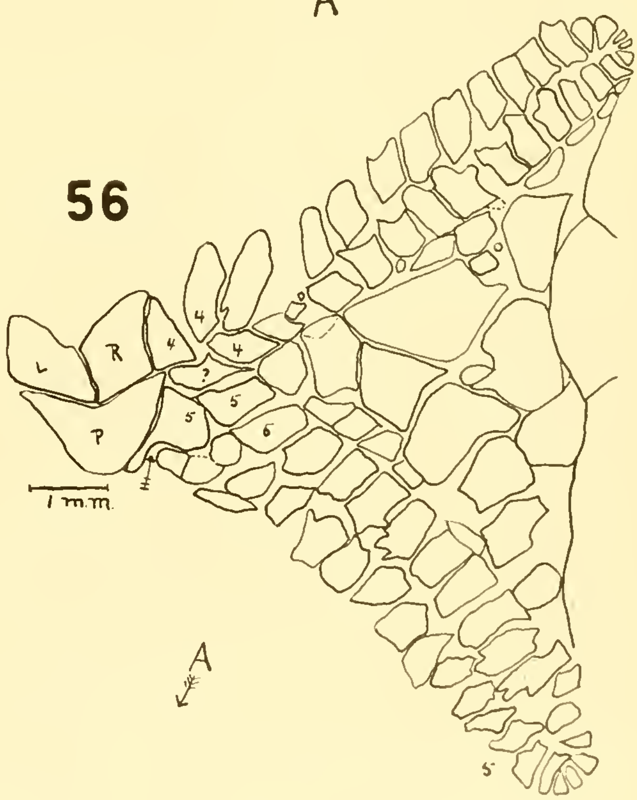


Stephen R. Williams.

EDITOR'S STATEMENT.

The Editor wishes to call attention to the fact that the OHIO JOURNAL OF SCIENCE is devoted to the interests of science in general and that its pages are open for the publication of articles from any branch of science. Since the subscribers to the JOURNAL are not confined to any particular field, the Editor is anxious to be able to publish as varied a series of articles as possible. Very few articles dealing with subjects other than the biological sciences have been offered. The Editor earnestly hopes that workers interested along other lines will be able to contribute more freely in the future and also that the contributions from the biological field may be of a more varied character. To this end he bespeaks the cooperation of all who are interested in an increased efficiency for the OHIO JOURNAL OF SCIENCE.

II. ARE THE TEN THOUSAND SMOKES REAL VOLCANOES?*

Robert F. Griggs.

In the original account of the discovery and exploration of the Valley of Ten Thousand Smokes in the National Geographic Magazine, February, 1918, I felt free to describe the phenomena in the light of our conclusions regarding them, although I could not, at that time, digress to give the data upon which our conclusions were based. This paper is written with the purpose of supplying the data that could not be elaborated in the former account, in order that the student of volcanic phenomena may judge for himself the validity of the conclusions reached.

It should be emphasized at the outset that, while there are certain conclusions concerning the nature of the Valley of Ten Thousand Smokes which may be considered to be well supported by indubitable evidence, there are also many larger problems looming in the background which as yet can hardly be stated with clearness, much less solved.

The primary question which must arise in the mind of anyone who considers the Valley is as to the nature of its activity. Are its smokes real volcanoes? Or are they of a more superficial character caused merely by the vaporization of surface water? It is evident enough that such a Valley full of "Smokes" might be due, either (1) to the percolation of surface waters down through the fragmental ejecta of the recent eruption to a flow of lava beneath, which, though erupted before the fall of ash, still retains a high temperature and vaporizes the water that comes in contact with it; or (2) the smokes might derive their gases from molten magma beneath the surface, in which case the vents would be as truly volcanoes as is Vesuvius itself.

Certain of the features of the Valley seem to favor each of these hypotheses. It will be well, therefore, to pass these facts in review. But before doing so, it will be desirable to

THE COOK STOVE OF THE EXPEDITION. *Photograph by D. B. Church*

This was one of the cooler vents, (100° C.). Comparison with page 107 will show how insignificant this is in comparison with the big vents shown in the distance. The notch in the contour of the hill at the right is the fault shown in detail on page 115, here two miles from the camera.

comment on the two hypotheses themselves. Everyone would prefer to explain the Valley as a superficial phenomenon, if such an explanation is possible, for that would bring into play nothing unusual in volcanic phenomena and would involve no far reaching theories. If, on the other hand, it is held that the smokes are truly volcanic, then it will have to be admitted that the formation of the Valley was an event without parallel among historic eruptions. More than that it would raise some fundamental questions concerning the nature of volcanism in general. Recognizing this situation, one ought to adopt the simpler hypothesis if it is at all possible to bring the facts into harmony with it. We shall begin, therefore, by marshalling the facts which support this view.

The very position of the smokes, in the bottom of a valley, suggests at once the likelihood of their being secondary products emanating from a stream of lava that has flowed down the Valley. If there had been any notable flow of lava toward the Bering Sea in connection with the eruption of Katmai, it would certainly have occupied a position not far different from the activity with which we are dealing. Truly volcanic vents, on the other hand, are in the great majority of cases situated on mountain tops rather than in valleys, although there is nothing to prevent their bursting through the floor of a valley.

PRACTICALLY ALL SURFACE WATER EVAPORATED IN THE HOT VALLEY.

The surface water hypothesis finds its strongest support in the indubitable fact that practically no water drains out of the Valley into the streams below. It is situated in a region of unusually heavy rainfall; half a dozen glaciers discharge their streams into it; and there are many square miles of snowfields which, during the warm weather of the summer, give forth a large volume of water. Several good sized streams start bravely out from the glaciers into the Valley, but as they course down their hot beds they dwindle until at the end of the Valley their united volumn forms a mud-choked brook only two feet wide and two inches deep. At times this stream probably stops altogether. How unusual this is in this country may be seen by comparing this stream with Martin Creek, whose basin is only half as large and contains no such notable glaciers.

Yet, on a warm day when the snow melt is large, Martin Creek is too big to ford. There can be no question, therefore, but that the greater part of the precipitation that falls in the drainage basin tributary to the Valley is returned to the air by evaporation.

Having ascertained this fact, we set out to see if we could follow the water cycle from precipitation to vaporization. In part this was easy. Whenever rain falls on the hot floor of the Valley it is immediately converted into vapor and returned to the air. During a rainstorm the Valley fairly reeks with the hot steam which is everywhere poured back into the saturated atmosphere. If one investigates the melting snowdrifts which fringe the Valley, he finds innumerable trickling rills

Photograph by R. F. Griggs

A BIG VENT FAR DOWN THE VALLEY.

The man silhouetted against the steam gives the scale, but only part of the steam column is shown, illustrating the magnitude of the vents which must be accounted for. This volcano is located 8 miles from Novarupta, where the activity of the Valley reaches its climax.

which start down from them, but they soon suffer the same fate as the pattering raindrops. Before they have crossed many yards of the hot earth, their waters become warm and dry up without having the opportunity to unite into a stream large enough to furnish water for a fumarole of any size. The larger streams likewise shrink so gradually that one cannot find a notable diminution in their volume in any particular place; that is to say, the vapor from their waters is given off diffusely along their whole length. When one considers the very large areas of the Valley where the ground stands at a temperature approximating the boiling point, it will be seen that its surface has the capacity of evaporating an enormous volume of water in addition to the great volumes of steam which come up from the specialized vents.

BIG VENTS NOT DUE TO DIFFUSE SURFACE EVAPORATION.

But such diffuse evaporation could not give rise to the great Smokes which give the Valley its character, for in these vents the production of steam is highly concentrated into small areas, where it bursts forth under pressure. To supply sufficient steam for the production of any one of these larger vents would require all the water of a good sized brook, but nowhere can any stream be found which goes up in steam all at once at a particular point. There are several places where a stream runs close beside a good sized vent. In a few places the steam was actually seen boiling up through cold water. But it appears evident on inspection of such places that the steam is quite independent of the brook, which merely happens to run over the orifice by which it finds exit. The brook is not sensibly smaller below such a place. Its temperature is not even measurably altered by the proximity to the hot vapor. (See page 102).

But places where watercourses cross lines of activity are uncommon. For the most part, the position of the vents bears no apparent relation to the streams, but follows a pattern of its own. The waters, seeking their level under gravity, course down through the middle of the Valley. But a great number of the largest vents come out of the marginal fissures which encircle the Valley about 200 feet above its floor. Throughout the Valley the vents are more prevalent along the crests of ridges than in hollows where water would collect. Many of the largest vents are thus located in situations where any great supply of surface water would appear most improbable.

DO THE SMOKES COME FROM VAPORIZATION OF GROUND WATER?

Such soundings as we were able to make in the throats of the vents confirm the view that they are more deep-seated than the surface drainage, for we could find no bottom with a stone tied to a hundred foot rope. This made it at once clear that they could not be formed by the vaporization of the surface streams. Perhaps they may come from the vaporization of subterranean streams which encounter a hot lava flow at some depth below the present surface. This supposition, it must be admitted, is wholly hypothetical since there is not otherwise any reason for suspecting the presence of such streams. Neither in the Valley itself nor in the country round about does one meet with evidences of underground water in any volume. It is a sandstone country whose strata, whenever exposed, appear unusually dry. No springs have been found, except in glacial or landslide debris. Since this view cannot be supported with evidence, it will be advisable to defer its consideration until some other aspects of the problem, concerning which there are more tangible data, may be taken up.

Photograph by R. F. Griggs

THE RIVER LETHE CROSSING A LINE OF FUMAROLES.

The steam in places actually bubbles up through the cold water. The volcanoes and the surface drainage manifestly have no connection with each other.

In the first place it will be advisable to consider the magnitude of the phenomena to be accounted for. The number of vents mounts up, literally, to several millions. Of these there are several hundred whose steam columns trail along before the constant wind for over a mile. (See page 100).

Many of these come forth from throats several feet in diameter. The largest, aside from Novarupta, which is a typical volcano, pours out of a yawning chasm about 20 feet across. Despite the size of the throat, the rush of the steam is so rapid that it fairly purrs as it comes rolling out. Many of the smokes with smaller throats issue under such pressure as to emit a continuous low-toned roar. In some of them the rush of the emerging steam is so rapid that a pebble tossed into them is either immediately spewed out again or sinks slowly down against the rushing current of rising steam. The supply of water necessary to maintain a constant flow of steam of such dimensions is, of course, considerable. Multiplied by the number of the big vents, it becomes enormous. Now, the visible surface water which is dissipated by diffuse evaporation appears to be great enough in volume to account for practically all of the drainage from the water-shed tributary to the Valley. One who sought to establish the presence of underground streams of sufficient size to produce the smokes observed would have considerable difficulty, therefore, in finding a source for such a quantity of water.

NO LAVA FLOW TO VAPORIZE GROUND WATER.

If the smokes are due to the vaporization of surface or ground water by a mass of hot lava poured out on the ground at the time of the eruption, it should be easy to find the lava flow beneath the fragmental ejecta which cover the surface. But none is to be found. There is absolutely no indication of any lava flow anywhere in the Katmai district other than the ancient basalts of which the volcanoes were built up. In many places deep canyons have been cut by the streams into the surface of the Valley, but nowhere is there the slightest indication of lava beneath. If there were a cooling lava flow close beneath the surface, the bottoms of these narrow canyons, which are 50 to 100 feet deep, (see page 118), should be much hotter than the surface of the ground, but such is not the case. These gorges are like any other part of the Valley. Locally they may be very hot, but these hot spots are always obviously associated with some special vent in the vicinity.

It is not only impossible to find any lava flow, but it is equally difficult to locate any vent from which such a stream might have come. Certainly it could not have come from the crater of Katmai. The low points in its rim are all occupied by glaciers which antedate the eruption, being covered by the same layers of ash as are found everywhere throughout the district. If any lava flow underlies the Valley, it must have issued from fissures in its floor. Such a fissure eruption is, of course, quite within the bounds of possibility. But we have now reached the stage where, in order to support our surface water hypothesis, we have had to assume the presence of both the lava flow, to be cooled, and the water, to be vaporized. It will now be advisable to consider the other side of the question.

Photograph by D. B. Church

THE VALLEY OF TEN THOUSAND SMOKES.

A corner of the Valley of Ten Thousand Smokes, looking from the rim of Novarupta toward Baked Mountain, July 15, 1917.

SMOKES ARE CONSTANT.

A large body of lava will obviously remain hot for a long time. It would be quite possible for such a mass, if it were present in the Valley, to retain heat enough to continue to send up clouds of steam throughout the six years which have elapsed since the eruption. But it will be recognized that this sort of activity would of necessity be gradually dying out. One should expect, therefore, to find a sensible diminution of the activity of the Valley with the lapse of time. On the contrary no diminution whatever can be detected. The smokes appear exactly the same now as when they were discovered. Compare the pictures above, taken in succeeding years.

The composition of the "smoke" from the vents is another matter of importance in this connection. If the smokes were due to the vaporization of surface water, which had come in contact with hot lava, they should be relatively pure steam. But as a matter of fact these vapors contain a large admixture of acid gases and deposit a great variety of sublimation products, such as sulphur and the two sulphides of arsenic. These

Photograph by J. D. Sayre

THE VALLEY OF TEN THOUSAND SMOKES.

Taken from almost the same spot as the picture opposite a year later, July 18, 1918. If anything the activity is greater than the year before. The little fumaroles found emerging from sandstone strata occurred in rocky slopes similar to, but around the corner from, those shown as dark spots on the mountain side in the middle distance.

products, both gaseous and solid, are now in process of analysis by the Geophysical Laboratory of the Carnegie Institution. These analyses, when complete, are expected to be made the subject of a special contribution, and no more than mention of the matter can be made at this time.

TEMPERATURES ABOVE 400° C.

The temperatures of the vapors are, likewise, matters of significance in this connection. If the smokes were due merely to waters coming in contact with the surface of hot lava, their temperatures should be in the neighborhood of the boiling point. As a matter of fact, however, all of the more active vents are much hotter than that. They are so hot that when we poked our walking sticks into them they came out blackened and charred from the heat. Once, before we were alive to the situation, we tried to take their temperature with a thermometer

Photograph by R. F. Griggs

TAKING THE TEMPERATURE OF A HOT ONE.

Many of the vents were so hot as to be beyond the range of the thermometers we carried the first year; so hot that the steam would char a piece of wood and did not begin to condense for some distance from the orifice. The expedition of 1918 measured temperatures up to 430° C.

tied to a stick. When we took it out, after momentarily plunging it into the hot steam, the string was burned in two, so that we almost lost our thermometer. The smoke emerges at so high a temperature that it is altogether invisible as it leaves the vent, and condenses only after it has travelled some distance through the cold air. (See pictures above). The vents were so much hotter than we had expected, that in 1917 we were entirely unprepared to measure their temperatures. The expedition of 1918, however, went prepared to cope with the situation. The records thus secured will be given in detail in a paper which is to follow. It may be stated in advance of detailed publication, however, that the temperatures measured ran above 400°C.

In many places the vents occur in lines that very strikingly suggest that their distribution is controlled by the presence of subterranean faults or fissures, which have been concealed by the

Photograph by R. F. Griggs

THE SAME VENT FROM A LITTLE DISTANCE.

The steam is so hot that it does not condense until ten feet away from the vent. Some idea of the scale may be gained from the realization that the little steamer enclosed by the circle was our cook stove, shown close up on page 98.

superficial layers of recent ejecta (see pages 108 and 109). In other places they emerge directly from yawning fissures, but the nature of the substratum is such that it is not easy to ascertain whether these correspond with rock fissures or are of a more superficial character. Where the vapor emerges from such wide open faults in the tuff that covers the Valley, it is obvious that these might be merely the superficial avenues of escape from the tuff, rather than the orifices of the true vents.

The linear arrangement in such cases may not be significant, therefore, but when there is no superficial break in the tuff corresponding to the line of smokes, it is difficult to explain their arrangement in any other way than as being outlets of a fundamental fissure in the bed rock. The writer, at least, can imagine no possible means by which such lines of smokes, often more than a mile in length, could be explained on the surface water hypothesis.

But although the volume of the emanations, their chemical character, their temperatures and their arrangement all give very clear and positive indications that they are true volcanoes,

Photograph by R. F. Griggs

LINES OF FUMAROLES ACROSS THE VALLEY.

A portion of the valley floor where the linear arrangement of the fumaroles is very conspicuous, indicating that they spring from fissures traversing its floor or encircling its edges.

we were very unwilling to consider the matter settled until we could find ocular evidence of their actual emergence from orifices in the bed rock underlying the Valley.

But this proved to be a matter of considerable difficulty, for the Valley is everywhere filled with a very thick deposit of the peculiar tuff which is discussed in the succeeding paper. There was good reason to believe, as will be seen, that the smokes did not originate in the tuff itself, but it so plasters up the Valley that it is difficult to ascertain the character of the ground from which they do emerge. As we prosecuted the exploration, therefore, we were constantly on the watch for evidence which would throw light on the source of the vapors.

FUMAROLES EMERGING FROM SANDSTONE STRATA.

Finally, far down toward the end of the Valley, we found a considerable area from which this tuff had been removed by erosion. In the bluffs of tuff still standing along the edges of this bare area, we found some sections where the whole length of the throat of a burned out fumarole had been exposed.

Photograph by J. W. Shipley

A NEARER VIEW OF A LINE OF FUMAROLES.

There is no surface indication of fracture. They probably spring from a deep-seated fissure.

These conduits ran clear down through the tuff to the bed rock beneath. (See page 110). At another place, we found a deposit on the surface of the bed rock which looked like that from an old fumarole, having apparently been formed by continued action of the fumarole after the erosion of the overlying tuff. We were not, however, satisfied with such evidence of burned out fumaroles, for there is always the possibility of misinterpret-

Photograph by R. F. Griggs

A FILLED CRATER IN THE MUD FLOW.

The crater was formed in the mud flow by explosive action originating below the base of the section, which here rests on undisturbed sandstone strata exposed by the stream in the foreground. This crater stood open during the explosion of Katmai, whose three-layered ash, marked K, may be plainly seen on the top of the original mud surface. Later there came a secondary flow of mud which filled up the crater and piled up about ten feet above the surface of the primary flow. The fill did not, however, choke off the fumarole which for some time maintained an open vent to the surface, shown in the photograph by a faint vertical streak rising from the bottom of the crater.

ing the character of such deposits. We were not willing to adopt so important a hypothesis unless we could find conclusive proof of its correctness. We were the more cautious in this matter because the underlying rock was not lava nor igneous rock of any kind, but sedimentary sandstone strata, as could be clearly seen in the bed of the adjacent stream.

Early in the exploration we observed the numerous fumaroles that come out of the upper slopes of Falling Mountain (see page 112). But since these occur in an ancient volcanic mass it was not certain that they could rightly be considered similar to the vents of the Valley.

Our uncertainties continued, therefore, until finally on the Broken Mountains, which are surrounded on all sides by the active vents of the Valley, we came upon several groups of small fumaroles which set at rest all possible doubts. They were located on almost precipitous slopes, (see page 105), from which all loose ejecta had slumped away, leaving the bed rock exposed to view. Here there could be absolutely no question, for the *little fumaroles were coming directly from the sandstone strata*, emerging from the crevices in the rocks which lay evenly bedded in undisturbed layers as originally deposited. The little crevices through which they found their way out had no doubt been broken open by the general disturbance, which so thoroughly broke up these mountains as to have suggested their name. But at these particular places the eruption had shattered the rock so little as not to disturb the position or arrangement of the original strata.

It is, of course, quite unnecessary to add that such fumaroles could not originate in the sandstone, but must have come from some mass of intruded magma beneath the surface. The very smallness of these little fumaroles made them all the more significant, for if these little wisps of steam were proven to come out from beneath the bed rock, the great columns of vapor in the adjacent Valley must as certainly draw their energy from the interior of the earth.

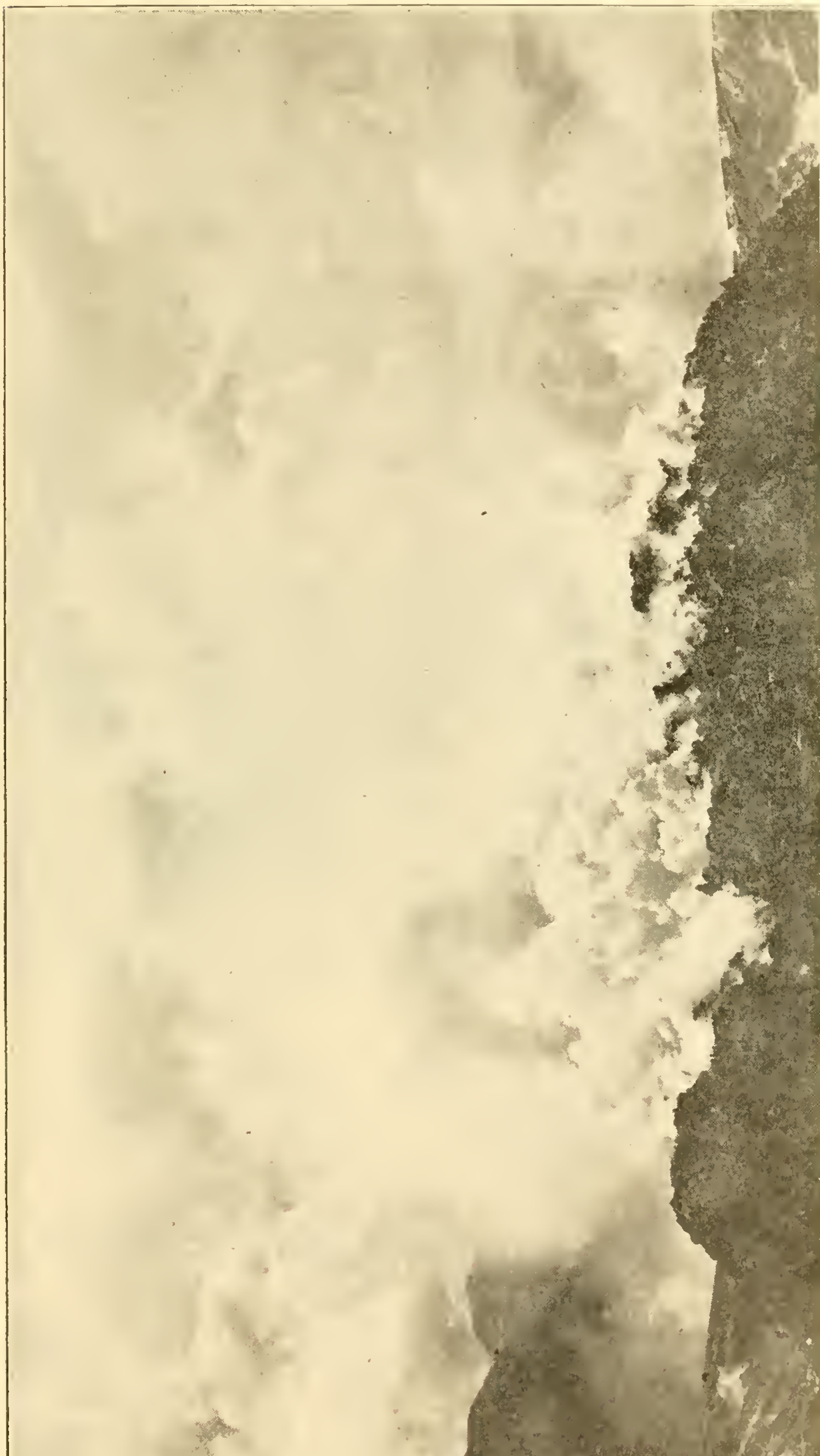
MAGMA REACHED SURFACE IN NOVARUPTA VOLCANO.

The magma that must thus underlie the whole of the Valley comes to the surface at one point—the crater of Novarupta (see pages 112, 113 and 114). This vent, which is in every way a typical volcano, has burst through the floor of the Valley like

Photograph by P. R. Hagelbarger

THE CRATER OF NOVARUPTA FROM THE HIGH POINT OF ITS RIM.

This volcano differs from the other vents of the Valley in that the lava here came to the surface, forming the plug which fills the throat. In the distance is Falling Mountain with numerous fissures issuing from crevices in ancient lava high above the Valley floor.



Photograph by R. F. Griggs

THE LAVA PLUG OF NOVARUPTA FROM THE CRATER RIM.

In the background at the sides may be seen the encircling wall of the crater.

the other smokes by which it is surrounded. Like them it is an absolutely new volcano, having burst forth in a situation where no volcanic activity had ever previously occurred. Its crater, which is 0.8 mile (1.25 km.) in diameter, is occupied by a plug of cooling lava that recalls the remarkable "spine" of Mt. Pelee. This plug is, however, much less conspicuous, being much broader, 800 ft., (250 m.) than high, 200 ft., (60 m.)

Photograph by P. R. Hagelbarger

DETAIL FROM THE LARVA PLUG AND CRATER RIM OF NOVARUPTA.

The broken pile of lava is about 200 feet high.

From this plug of lava are still given off great quantities of gases which in calm weather ascend 10,000 ft. into the air, forming great clouds that obscure the sky for miles around (see page 113). The history of Novarupta began with a period of explosive activity, during which it threw out a great mass of ash and pumice, forming deposits 50 feet thick or more in the vicinity of the vent. This explosive activity, which is shown by the sequence of the deposits to have occurred before that of Katmai, was much less violent than that of its greater neighbor, as may be judged from (a) the larger size of the cinders thrown out; (b) the greater depth of the deposits immediately around the vent, (see cut below); (c) their lesser distribution, for they cannot be identified beyond a few miles from the volcano. At the close of this explosive period a conspicuous crater ring was thrown up around the vent. This was followed by the gradual extrusion of the lava plug.

Concerning the size, condition, and geological relations of the other portions of the mass of subterranean magma, we are of course, left entirely to speculation. There are the best of

Photograph by R. F. Griggs

A FAULT SCARP ON BROKEN MOUNTAIN.

The man gives the scale. This is the same fissure as that shown in the distance on page 98. The visible face of the scarp is composed of stratified ash, mostly from Novarupta. The sequence of the ash strata shows that Novarupta burst forth before the explosion of Katmai, but this faulting occurred after the eruption.

reasons for supposing that it approaches closely to the surface over the whole area of the Valley, and over Katmai Pass as far as Observation Mountain as well, for over all of this area there is clear evidence of fumarole action. The sections through the tuff described above, which gave us our first intimation that the steam might reach the surface through the sandstone, were almost at the very foot of the Valley, 13 miles from Novarupta. Some of the largest and hottest of all the volcanoes, e. g., that pictured on page 100, occur far down toward the foot of the Valley, indicating as definite a connection with the subterranean magma at that point as in the upper Valley, where large vents are more numerous. The whole area, thus giving evidence of the near approach of the magma to the surface, is 20 miles (32 km.) in length, 9 miles (14.5 km.) in greatest breadth and covers an area of 53 square miles, (137 sq. km.).

The recognition of the fact that the Valley is truly volcanic inevitably raises some questions of great interest and importance. What are the geological relations of the magma beneath? What are the reasons for its bursting through in this particular Valley? Is it a batholith rising from the interior? What is the relation between the formation of the volcanoes of the Valley and the explosion of Katmai? Did the eruption bring about any changes in the relative elevations of the several areas concerned? Why does the Valley run transverse to the main line of volcanoes which follows the axis of the peninsula? These and other fundamental questions of similar character open most fascinating problems for future study. If, as seems possible, some of them can be solved, the study of the Valley of Ten Thousand Smokes will have taken us several steps nearer the solution of the greater problem of volcanism and its relation to diastrophism. But we are not yet in a position to attempt the discussion of these matters.

Scientific Results of the Katmai Expeditions of the National Geographic Society.

III. THE GREAT HOT MUD FLOW OF THE VALLEY OF TEN THOUSAND SMOKES.*

Robert F. Griggs.

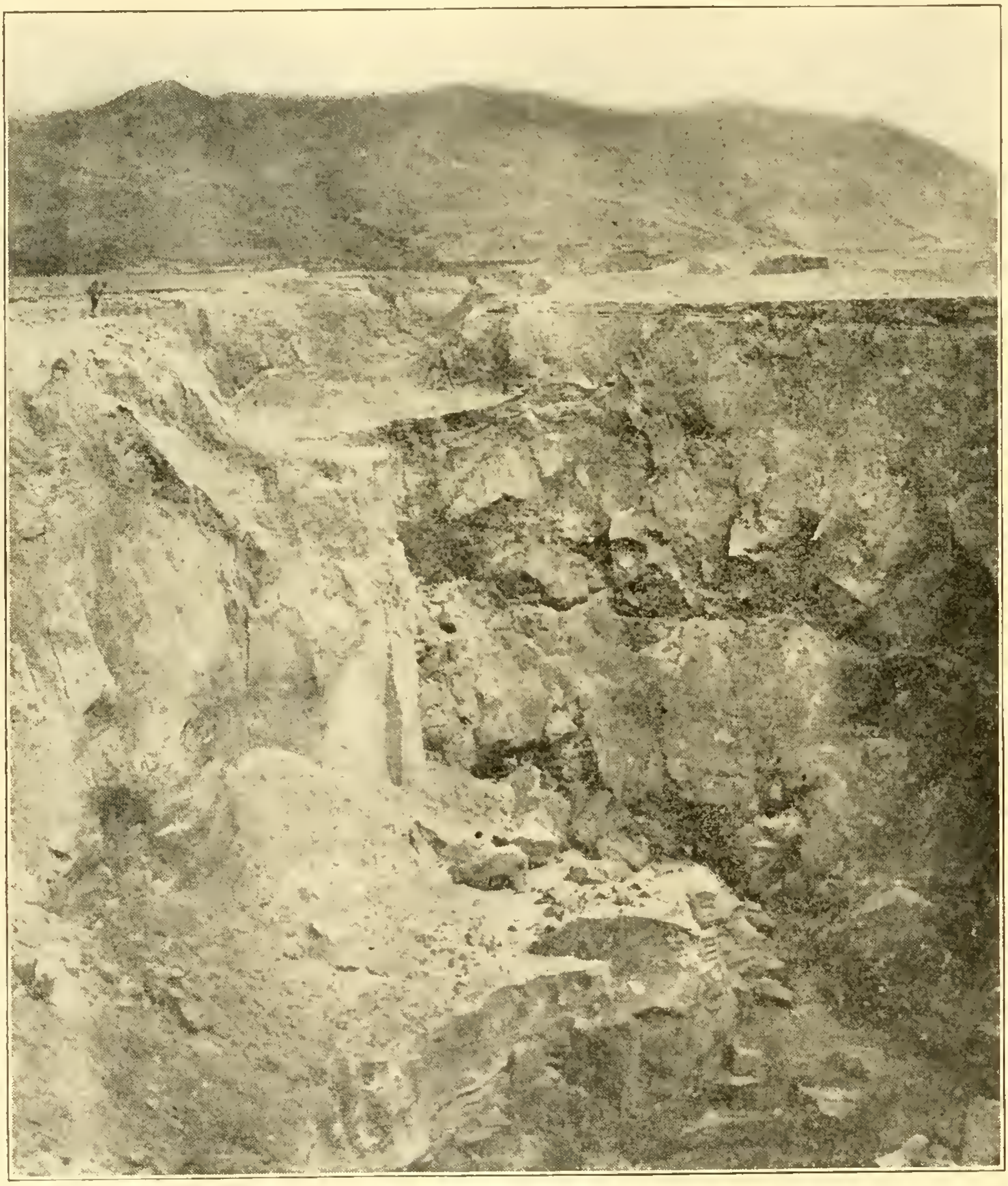
As we explored the Valley of Ten Thousand Smokes, the first thing that attracted our attention, when we could look beyond the smokes themselves, was a curious line that encircled the Valley almost like the high water mark of a flood. Above this line were the ordinary gray ash slopes, below it was a great mass of compact hard tuff of a terra cotta color quite different from the ordinary ash.

Examination disclosed the fact that the floor of the Valley is covered with a massive deposit of enormous thickness, which has no counterpart on the surrounding hills. The interpretation of the character and origin of this deposit was, for a long while, our chief problem as we explored the Valley and its branches, for its evident peculiarity at once excited our curiosity.

The difficulty was not that its relations were obscure, for they are so obvious as to suggest the interpretation at first sight. The trouble was that this evident explanation was so seemingly impossible that we were altogether unwilling to accept the testimony of our senses until the evidence became so overwhelming as to eliminate the possibility of further doubt.

Since returning from the field, we have held the matter in reserve, until we could thoroughly digest the evidence and talk it over with some students of volcanism in whose judgment we had confidence. When the matter was first put before these men, it was met with the most violent opposition. They uniformly reacted to the proposition exactly as we had ourselves when we first encountered it in the field. But in the end, when the evidence was presented and all objections answered, without exception they accepted the interpretation as the necessary consequence of the facts.

I have thus entered into a somewhat personal statement of the matter because I must expect my readers, at least those who have any previous acquaintance with volcanoes, to assume the same attitude and would bespeak in advance their careful consideration to the end, rather than the unceremonious rejection which would otherwise be the fate of the account.



Photograph by R. F. Griggs

A CANYON NEARLY 100 FEET DEEP, CUT INTO THE MUD FLOW.

Although this section is located far down the Valley, it shows no indication of the bottom of the mud flow. The thin strata of the Katmai ash may be seen near the top. The figure at the left gives the scale.

I would further add that I am not committed to any theory of the origin of this curious terrane, but will be glad to accept any other interpretation that can be suggested, provided only that it is consistent with the facts as found in the field. Certainly any suggestion that would relieve us of the necessity of postulating an entirely new type of volcanic action will be most welcome.

VALLEY OF TEN THOUSAND SMOKES FILLED WITH A GREAT DEPOSIT OF TUFF.

Surrounded as it is by high and rugged mountains, the most striking feature of the conformation of the Valley of Ten Thousand Smokes is the flatness of its floor. One could ride a bicycle for miles along its smooth surface, and there are many places between the lines of activity that would be ideal landing fields for airplanes. (See map, page 138).

Where the drainage gullies have gashed this surface, its flatness may be seen to be due to the smooth top of the terra cotta tuff already mentioned. The traveller peers into these canyons in the hope of finding some clue to the thickness of this massive tuff, but in this he is disappointed. In such places one finds cuts of 40, 60, or even 100 feet down into its mass, but none of these, in the upper portion of the valley, reach its base and reveal the character of the formation beneath. This is not only very puzzling, but very impressive as well, for when one finds that it is more than 50 feet thick over wide areas, it becomes evident that the volume of the formation is enormous. Our inability to find any section through it was rendered the more significant by reason of the fact that almost all of the trenches in it are located not in the middle of the Valley, where it might be supposed to be thickest, but along the edges where a minimum thickness would be expected. (See page 118).

The enormous volume of this mass was further emphasized as we extended our exploration through the Valley, for then it became evident that the area covered by it was much greater than had appeared from the head of the Valley. First we found the branch valley heading in the Broken Mountains covered with it. Then we saw the great valley between the Broken Mountains and Knife Peak all filled in the same way, clear back to Novarupta Volcano, forming with the main valley a complete circuit around the Broken Mountains. Finally, before we came to its extremity, we had reached a distance of 20 miles (32 km.) from the point where we first encountered it back of Observation Mountain, and 15 miles (24 km.) from the divide back of Novarupta Volcano. Altogether it occupies an area of 53 square miles (137 sq. km.). At its highest points, on the divide back of Novarupta and in Katmai Pass, it reaches an altitude of about 3,000 feet, while at the other extremity it extends down to within about 300 feet of sea level.

Photograph by J. D. Sayre

"HOODOO" NEAR FISSURE LAKE.

Characteristic "Hoodoo" weathered out of the solidified mud near Fissure Lake. The stratified ash from Katmai lying on top of the massive mud flow is well shown at both right and left.

Everywhere, in appearance and structure, this formation closely resembles the Katmai mud flow. In color and character the material of the two are of almost identical appearance, being darker and finer than the other ejecta of the recent eruption. They have the same total absence of stratification or of horizontal cleavage planes, contrasting most strongly with the thin beds of the stratified ash. Where cut into by erosion or sheared by faulting, they break with irregular fractures running in any direction with the line of stress. By reason of the character of their cleavage, they are often broken or weathered into the most fantastic blocks, like the hoodoos of the bad land region, (see pages 118 and 120).

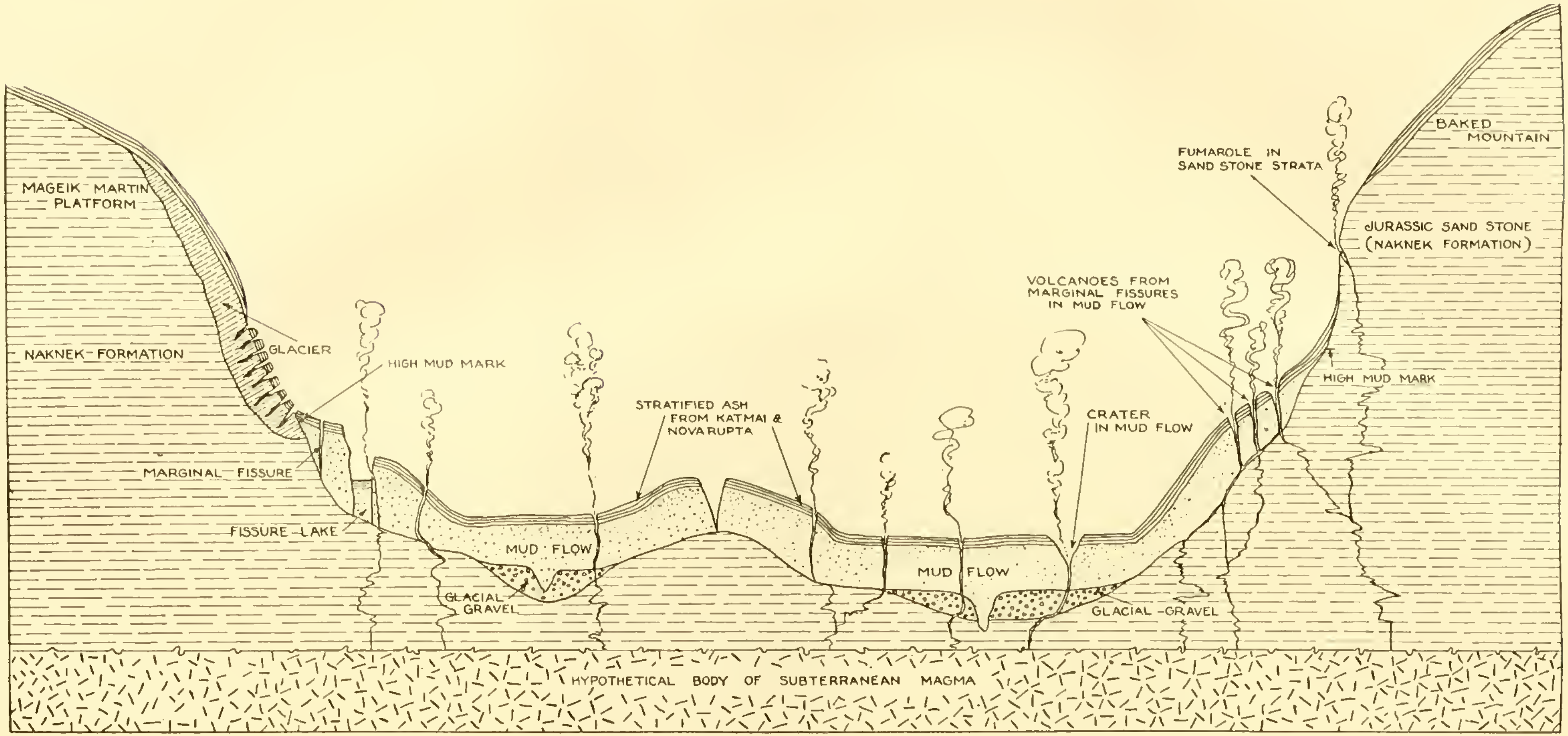
The bulk of it is composed of very fine dust-like particles, closely packed together until they form a compact, homogeneous mass. But in this mass are included numerous lumps of pumice and fragments of rock of all sizes, sometimes in large quantities, but always without any trace of sorting or stratification, except where the material was obviously subject to secondary readjustments.

Photograph by C. F. Maynard

LOOKING TOWARD KATMAI PASS FROM BAKED MOUNTAIN.
The high mud mark sloping down into the Valley on each side of the mud flow is very evident.

VALLEY SURROUNDED BY A CONSPICUOUS "HIGH WATER MARK."

The "high water mark," separating the chocolate tuff-covered basin of the Valley from the gray ash slopes of the mountains before alluded to, impresses one more and more as he studies the phenomenon. It follows, in a general way, a contour line 200 to 360 feet above the floor of the Valley. While it thus reminds one of the shore line of a pond, it is obviously



A GENERALIZED SECTION OF THE VALLEY OF TEN THOUSAND SMOKES.

Taken approximately on a line connecting the summits of Knife Peak and Mt. Martin. For the sake of compactness sections of the branches of the valley between Baked Mountain and Knife Peak are omitted, although they also were filled by the mud flow and contain many active volcanoes. The thickness of the mud flow and all data indicated below the surface of the ground are, of course, purely hypothetical.

not precisely level like the shore of a lake, but is subject to variations in level so large as to be easily discernible to the eye without the use of instruments; as though the Valley had been filled with a heavy, viscous fluid like tar, which, as it flowed down the Valley, had succeeded only imperfectly in finding its level. The most conspicuous example of this is in the southwest corner of the Valley under the glaciers of Mageik, where the "high water mark" is more than a hundred feet lower than further east along the foot of Mount Cerberus. But the same departure from a precise level appears in many other places. (See pages 121, 130 and 136).

All around the margin of the Valley, just below the "high water mark," runs a series of gaping fissures, as though the surface had been stretched by subsidence after its formation. Conditions remind one of a temporary puddle which, after having frozen over heavily during a rise in a river, is drained again so as to let the ice down onto the bottom with consequent stretching and cracking all along the shore. The analogy is carried further by the criss-cross cracks, which run in all directions across the surface like the contraction cracks in a frozen pond. (See page 108). Where the ridges from the shoulders of the mountains project into the Valley, the marginal fissures coalesce and run far out into the Valley in just such a Y form as do the ice cracks at the point of a peninsula in our drained pond. In another place, where there was apparently a considerable detached hill in the floor of the original valley, there remains a high area whose crest is occupied by a notable fissure, just such as occurs when the ice is let down over a similar hump in the bottom of a pond. (See page 122).

About ten miles down the Valley there is a distinct horizontal line of the same red material a hundred feet above the present "high water mark," just as though the liquid that filled the Valley, standing for a little while at this higher level, had "frozen" a little along the bank before subsiding.

The reader may perhaps wonder by this time why, when there were such clear indications that this was a mud flow, we had any hesitancy in calling it such at once. But to us, as we worked in the field, the reason was evident enough. By no hypothesis that we could invent were we able to suggest a source of the material.

TUFF OF VALLEY SIMILAR TO KATMAI MUD FLOW, BUT FORMED BEFORE THE EXPLOSION.

There was no such difficulty in the case of the Katmai Mud Flow, for in the last spasms of the eruption great quantities of finely divided mud were thrown out on top of the coarse ash and pumice deposited in the earlier stages of the eruption. Part of this, wetted up perhaps by the heavy rains that followed the eruption, slumped down off the ash covered slopes into a

Photograph by D. B. Church

A SECTION OF THE KATMAI MUD FLOW.

Contrast with the section of the Great Mud Flow given on page 132. Here the mud flow occurred after the ashfall which lies beneath it on the original surface of the ground whose irregularities the strata follow. The bushes show no sign of burning, either here or where they protrude through the mud flow. Stratified ash here fifteen feet thick.

narrow gulch at the foot of the mountain. Material from a large area was thus gathered together into relatively restricted compass, forming a notable deposit many feet in thickness and over two miles long. Although there were no eye witnesses of the Katmai Mud Flow, there is the best of proof that it occurred after the eruption, and probably in the manner stated, for the upper slopes of Katmai are still plastered with mud like that which slumped off, and the mud flowed down over the stratified ash, which is everywhere found beneath the mud flow, showing clearly that the latter occurred after the ashfall. (See page 124).

But in the Valley of Ten Thousand Smokes conditions are reversed, for the great mass of tuff which forms its floor is everywhere overlain by the stratified ash from Katmai, (see pages 110, 118, 120, 132, 136 and 140), proving that it must have been in position at the time of the ashfall. When it was realized that the great mass of tuff in the Valley had originated before the ashfall, its interpretation became more of a puzzle than ever, for everything indicated that it was no ancient formation, but belonged to the present eruption. Mud flows of the type of that formed on Mt. Katmai have frequently occurred after eruptions, but nothing like this, occurring as a preliminary to an eruption, is described in the literature with which we are familiar.

TUFF OF THE VALLEY HAS NO COUNTERPART ON THE SURROUNDING MOUNTAINS.

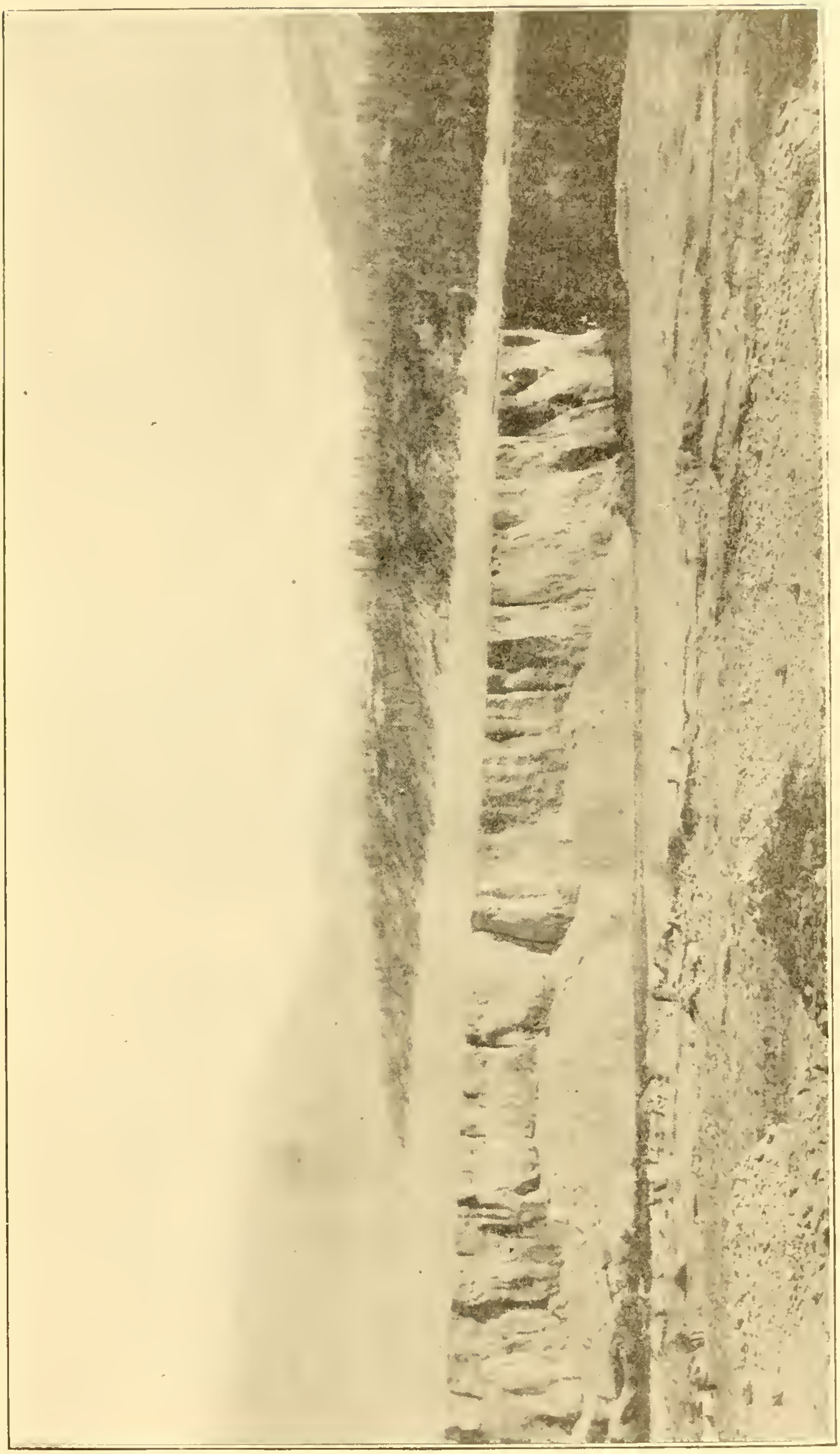
In view of these anomalous conditions, we felt that to adopt the hypothesis that the tuff of the Valley was a mud flow would raise more problems than it would solve. Such a supposition appeared, therefore, of little value in interpreting the Valley. We were left for a long while, therefore, without any hypothesis whatever to account for what we saw.

Nevertheless, detailed examination of the surrounding mountains confirmed the suggestion of the "high water mark"—that the tuff was confined to the floor of the Valley—for it had absolutely no counterpart on the slopes above. They were everywhere clothed with the same strata of ash as covered the tuff itself. This stratified ash always rested directly on the original surface of the ground—bed rock or old soil as the case might be, without the slightest indication of anything corresponding to the massive deposit in the Valley.

Photograph by P. R. Hagelbarger

LOOKING UP THE MUD FLOW ALONG ITS EDGE.

At the left, undisturbed forest above the high mud mark; in the center the charred stumps of trees, that were burned off by the mud, exposed by later erosion.



Photograph by P. R. Hagelbarger

LOOKING ACROSS THE MUD FLOW NEAR ITS TERMINUS.

Nearly panoramic with the picture on the opposite page. At the left, stumps of burned trees exposed by erosion. In the distance, the undisturbed forest above the high mud mark. The layers of Katmai ash may be made out as a line across the face of the bluff below the forest, between primary and secondary mud flows.

ENGULFED TREES SHOW THAT THE TUFF MUST HAVE ORIGINATED AS A FLOW OF MUD.

Finally, when our work carried us down the Valley toward Naknek Lake, we found conditions, which, while rather adding to the anomalies already puzzling us than explaining them, yet gave such clear cut and positive evidence of the mode of deposition of the tuff as to make its character certain.

In the lower Valley, where the remains of the former forest still persist to tell the tale, the "high water mark," or as it had better be called the "high mud mark," becomes even more conspicuous and significant than it is in the upper Valley. Whatever our doubts may have been before, no matter how great the difficulties of explanation that remained, one glance at the remains of the forest embedded in this tuff was all that was needed to convince everyone that we were dealing with a gigantic mud flow. Right down to the edge of the erstwhile mud the trees stand undisturbed, but below that level they are overriden, twisted and bent before it in such fashion as could not have been done except by a moving liquid. The absolute sharpness of this line separating the uninjured forest from that covered by the moving mud is plainly shown on the photographs reproduced on pages 126, 127, 128 and 136.

At the bend in the Valley, where the forest begins, the mud flow encountered a belt of irregular morainic hills among which it pursued a most irregular course, overtopping some, leaving others standing free above the surface, slopping over into the ravines, and in every way showing that it was once highly liquid. In this vicinity a strong stream, now furnishing the greater part of the water of the Ukak River, was dammed by the mud flow, forming a deep lake. Since the mud flow hardened, the waters of this stream have cut down 20 or 30 feet into this dam, but there still remains a lake a mile long and half a mile wide. Beyond the bend in the Valley the mud flow continued on for more than a mile, gradually thinning out until for some distance back from the tip it is only 10 feet thick, in striking contrast to its great thickness and massive character further up the Valley. Everywhere the mud shows a surprising capacity to adjust itself to the variations in the level of the ground over which it flowed. At one place, near the middle of the level flow, I noticed a tree or two sticking up through the mud, and upon investigation found that their roots were only about a foot beneath the surface. They had grown on the summit of a morainic hill which, after having been deeply buried, had been almost laid bare again by the readjustment of the mud after the first wave had passed.

But there was none of that evidence of violent damage which would have accompanied the rush of a flood of water down the Valley. Although the bushes were bent and twisted

Photograph by R. F. Griggs

THE EDGE OF THE MUD FLOW.

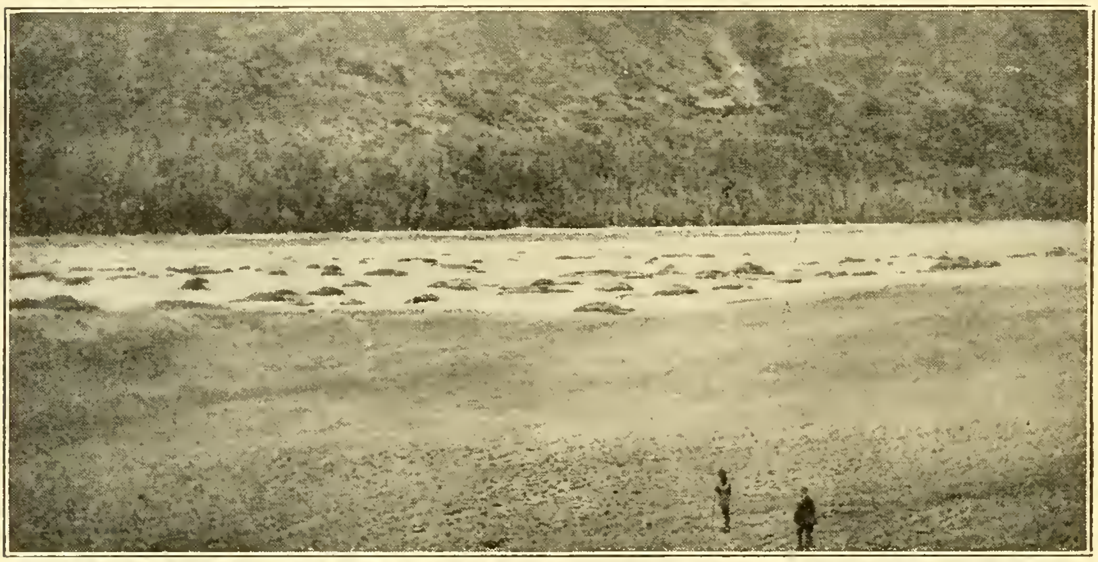
The burned and broken remnants of the trees below the high mud mark stand in strong contrast to the undisturbed forest which, though killed by the eruption, was beyond the reach of the mud.

beneath its weight, they were not broken nor uprooted as they would have been if the heavy mud had rushed upon them at a high speed.

EVERY STICK BURIED BY MUD FLOW REDUCED TO CHARCOAL.

Near the edge of the mud flow a few trees remained sticking up out of the mud. When we took hold of these we found to our astonishment that they had been burned off a foot beneath the surface. Later, in sections where the flow had been cut into by erosion, we found that every particle of wood that had been buried by the mud had been turned to charcoal. In some places we found the mat of old tundra vegetation, transformed into a thin sheet of charcoal, lying between the mud flow and the old surface of the ground. Some of the trees engulfed had been a foot in diameter, but they were as completely charred as the fine twigs. (See pages 126, 127, 129, 132, 133 and 134).

Upon finding this evidence that the flow had consisted of hot mud, we began to wonder whether the Katmai Mud Flow had likewise had a high temperature. It was with great interest, therefore, that we awaited an opportunity to examine the Katmai Flow again to see if we had overlooked evidence of



Photograph by J. W. Shipley

ACROSS THE MUD FLOW NEAR THE LOWER END.

The bare surface of the mud contrasting with the forested slopes beyond and the definite level of the opposite edge are characteristic. The mounds in the middle of the flow are small fumaroles which have caught and cemented together piles of the ash blown before the wind.

such a character. But when we re-examined it, we found that in this respect it was altogether different from the Great Mud Flow. The wood which it had buried was as white and clean as though bleached in the sun. Its mud had been cold, therefore, just as would be expected of mud soaked up by excessive rains.

It was now fully proven that the tuff lying on the Valley floor was a mud flow of stupendous proportions, but this certainty, instead of settling our problems, had raised a host of new questions more puzzling than the original ones. The fact that it had completed its course down the Valley before the ashfall, by removing the possibility of its having come from the blowout of Mt. Katmai, made it more difficult than ever to find the source of the material. The high temperature which characterized the moving mud definitely put it into a different class from the Katmai Mud Flow. And the freshness of the plant remains and other features combined to fix its date as immediately prior to the explosion of Katmai.

MUD FLOW VERY DIFFERENT FROM A LAVA FLOW.

One way out of these difficulties at once suggested itself. If we could consider this formation a lava flow rather than a mud flow, its explanation would be easy, for a lava flow of such dimensions would be nothing remarkable. But lava comes from a mass of molten magma which solidifies into crystalline rock. By no stretch of the meaning of the term can this tuff be considered crystalline rock. It is composed of fragmental materials like the ash that settles out of the air. Although compacted into a firm mass, somewhat resistant to the weather, it crumbles to powder between one's fingers. Though hot by human standards of comparison, its temperature was far below the melting point of any lava, for, although it reduced the trees which it engulfed to charcoal, it did not, at least in the lower Valley, set fire to the forest above the high mud mark, nor even consume the trees that were not completely covered up. On the contrary, the projecting parts of the burned trees were sound and untouched by fire. Where cooled by the atmosphere, or by the underlying soil, the mud had evidently lost its heat before charring was complete, for the stumps were not burned clear to the ground and good sized branches were charred through only when buried a foot beneath its surface. This indicates that the charring was a gradual process rather than any sudden combustion, such as breaks forth when a lava flow pours through a forest. (See page 133).

ATTEMPTS TO EXPLAIN IT AS A MUD FLOW OF THE USUAL TYPE.

When it thus became evident that our flow of hot mud could not be considered a lava flow, the most probable explanation seemed to lie in interpreting it as a mud flow of the conventional kind, formed from the ejecta of some previous eruption. Such a hypothesis would of course leave its temperature unaccounted for, if indeed it were not inconsistent with the observed temperature relations; but if its other features could be accounted for on such an assumption, its high temperature might perhaps be explained by some subsidiary hypothesis.

If the mud flow were thus the product of a previous eruption, it would be expected to have been formed immediately after that eruption, like the Katmai Mud Flow, before the mass of mud had had time to dry up and "set." For, once such a mass of mud dries out, it would not be likely to be soaked up

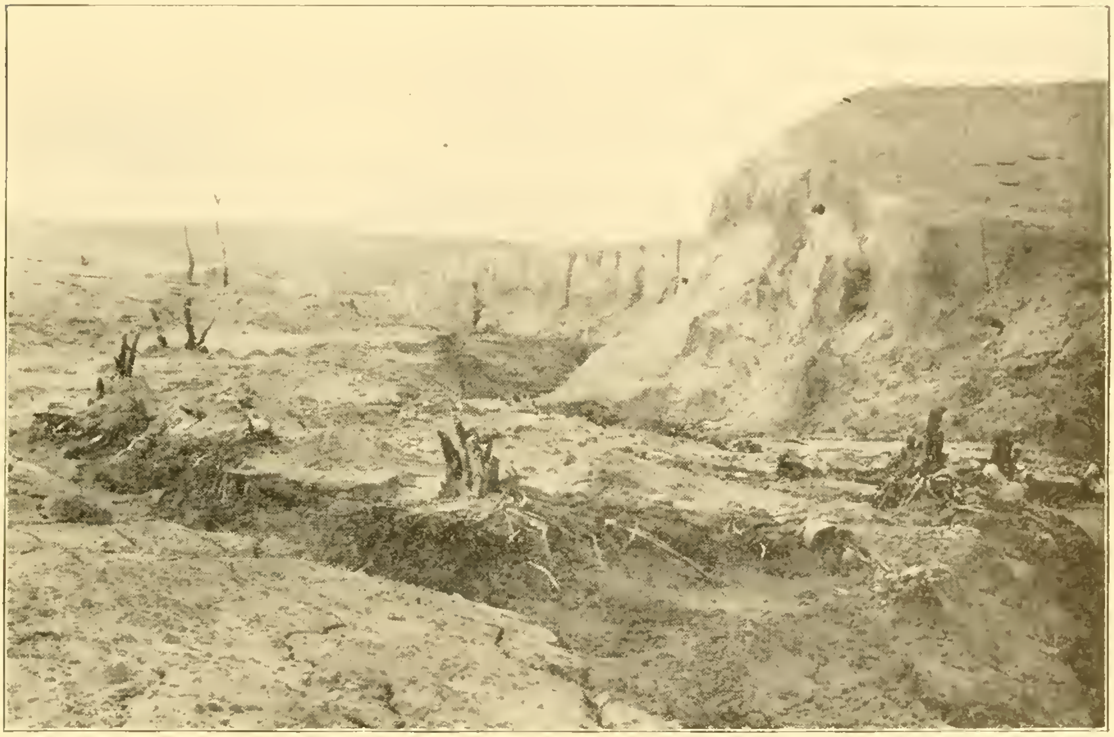
Photograph by L. G. Folsom

A STREAM CUT SECTION NEAR THE TOE OF THE MUD FLOW.

The engulfed tree is completely reduced to charcoal. The section shows (a) piles of debris lying on the original surface of the ground; (b) the unstratified mass of the mud flow; (c) the three layers of the ash from Katmai; (d) a mass of secondary outwash deposited by the stream which later cut the section. The wash of this stream broke off the part of the tree protruding above the mud flow.

again en masse in such a manner as to permit the formation of such a tremendous quantity of mud all at once. Indeed, I can imagine no process of nature by which the present hardened tuff could be changed back into liquid mud.

But the condition of the burned trees is unequivocal proof of the recent date of the mud flow. It occurred so recently that there has been no time for the protruding parts of trees to decay since they were killed. Even the small twigs of the dead trees are still in place, giving positive evidence that the



Photograph by R. F. Griggs

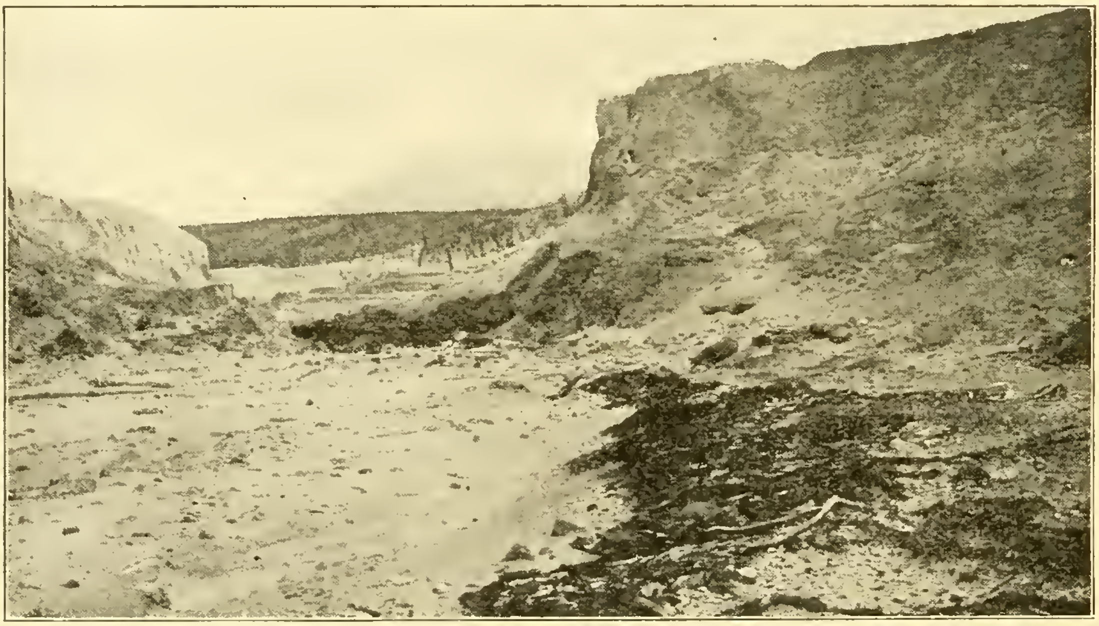
STUMPS OF TREES BURNED OFF BY THE MUD FLOW.

Exposed by later erosion. It is to be observed that the mud was so cooled by contact with the soil that it did not burn the stumps clear to the ground. The roots protected by a few inches of soil were not burned at all.

mud flow must have occurred very recently, (see pages 126 and 129). There is everywhere a conformity between the mud flow and the overlying ashfall that of itself negatives the possibility of an interval of erosion between them. There are, moreover, occasional evidences that the mud was still fresh and liquid at the time of the ashfall. There are a number of places where local adjustments of the mud occurred after the ashfall. In such situations a secondary flow of mud lies above the layers of ash, (see pages 110, 136 and 140). All lines of evidence thus converge to show that the mud flow occurred immediately before the explosion of Katmai.

NO OLD MATERIAL FROM WHICH MUD FLOW COULD HAVE BEEN FORMED.

If, therefore, this mud flow is to be interpreted as a secondary deposit produced by the working over of the original ejecta of some previous eruption, it will be necessary to suppose that some of the preliminary events of the present eruption, such, perhaps, as the melting of a large quantity of snow, occurred in such a way as to soak up a mass of old mud lying on the mountains and start it down into the Valley. With this possibility in mind, we searched the mountains for some



Photograph by R. F. Griggs

MAT OF VEGETATION REDUCED TO CHARCOAL BENEATH THE MUD FLOW.

The original surface of the soil has been uncovered by erosion.

remnants of an ancient stratum of mud. But not the slightest indication of any such deposit could be found. It was our custom to examine and measure sections, cut by streams through the layers of ash, wherever found. In all the sections examined the ash from Katmai lay directly on bed rock or old soil as the case might be, with no such mud deposit intervening. Yet it would be altogether impossible for every trace of so extensive a deposit to have been turned into mud and carried into the Valley. Any deposit thrown into the air from a crater would be spread, in small quantities at least, over a great expanse of country. The mud that gave rise to the relatively insignificant Katmai Mud Flow is recognizable as a distinct stratum on top of the rest of the ashfall over all of the mainland country as far away as the seashore. The mass of the mud in the Great Mud Flow is so many times greater than this that traces of the antecedant bed from which it came would certainly have been found somewhere, if it was produced in a manner at all resembling the mud of the Katmai Flow.

The only geologist who ever visited the district, before the eruption, was J. E. Spurr, who in 1898 crossed Katmai Pass, traversing both Katmai Valley and what is now the Valley of Ten Thousand Smokes, then an ordinary grass covered valley. His account makes no mention of any deposit of fragmental volcanic material of any sort. Since the discovery of the mud flow I have had the opportunity of talking the matter over with Mr. Spurr, who stated, in the most positive terms, that there was no such deposit along his trail. And, as will be shown below, the distribution and slopes of the mud flow are such that part of it must have originated in Katmai Pass, which he crossed. But let us assume, for the sake of the argument, that a deposit of the mass and character requisite for the formation of the mud flow was actually present before the eruption, even though no trace of it has been found by any of the parties that have explored the district.

NO DRAINAGE AREA FROM WHICH IT COULD HAVE BEEN CONCENTRATED.

Such an assumption immediately raises one of the difficulties that confronted us in our first efforts to find a source for the mud of the Valley. The area of the broad Valley is so great, in proportion to the steep slopes of the surrounding mountains, that there is no tributary drainage area around its upper end large enough to have served as a collecting ground from which the mud could have come. The mud flow thus covers almost half of the drainage area from which it could have come. Its area is 53 square miles, while that of the whole basin is only 110 square miles. If these mountain sides supplied the material that now covers the Valley, they must have been everywhere covered to a depth approximately equivalent to the present thickness of the tuff of the Valley, i. e., at least 50 feet. This is

Photograph by J. D. Sayre

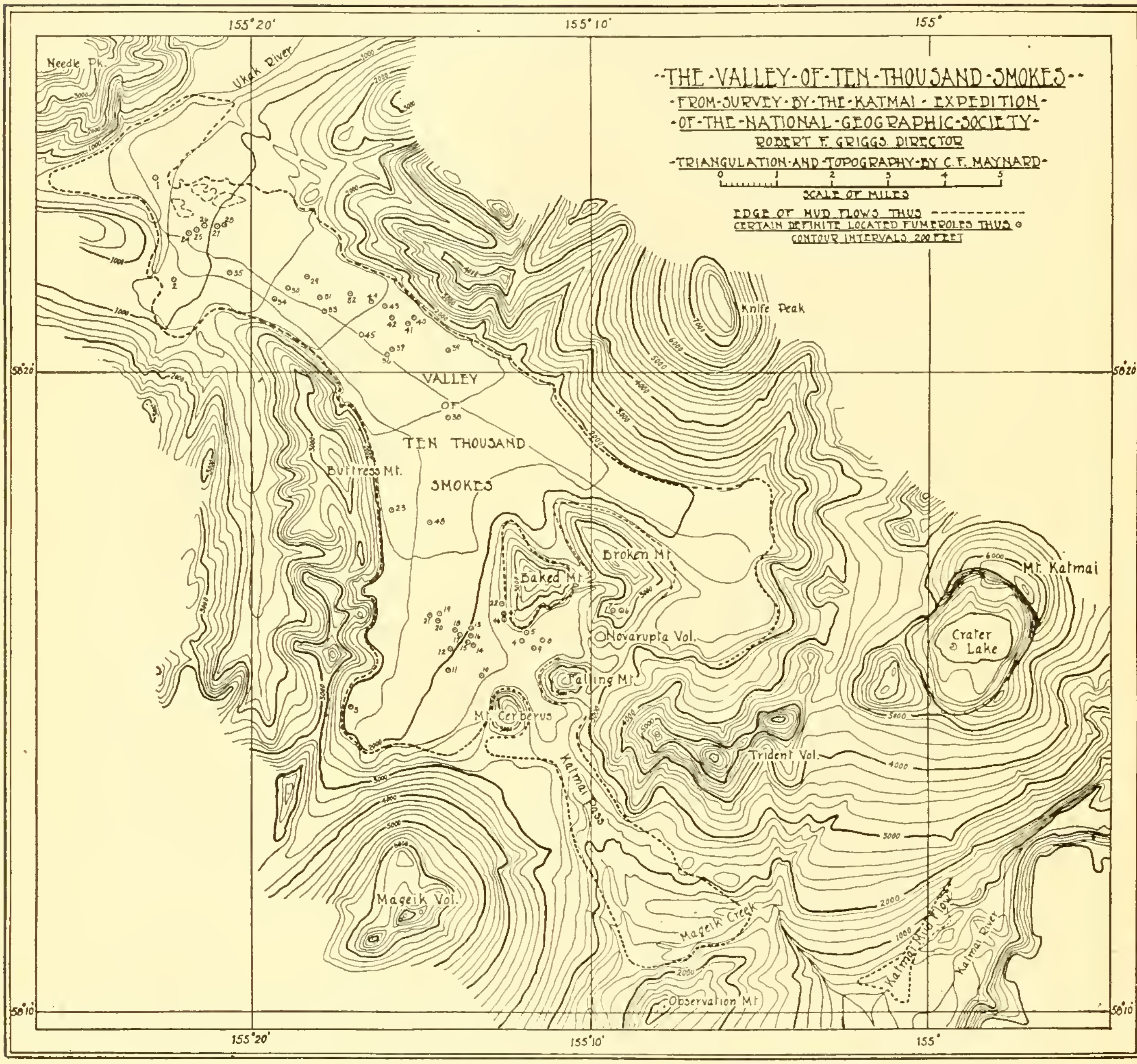
A CANYON ERODED IN THE MUD FLOW NEAR ITS TERMINUS.

The high mud mark and the undisturbed forest above it well shown at the right. In the bluff below the forest, the line formed by ash from Katmai may be made out between primary and secondary flows of mud.

on the impossible assumption that the whole of every slope tributary to the Valley furnished its share of the mud. Whereas it is manifest, from its gravitational relations and the position of the high mud marks, that the mud could by no chance have come from more than a small fraction of the watershed, (7 square miles). The contrast between the Great Mud Flow and the Katmai Mud Flow in this matter is very striking indeed, for in that case the collecting ground, (5 square miles), was eight times as great as the area at present covered by the mud, (0.6 square miles). See map, page 138. But let us waive this difficulty and go on with the consideration of the situation assumed.

NO WATER SUFFICIENT TO LIQUIFY THE MUD IF THE MATERIAL WERE PRESENT.

To transform such a vast quantity of dry tuff or dust into mud would require an equally vast quantity of water. The volume of the mud flow, while not accurately known, is of the order of one cubic mile. To hold this quantity of solid material in suspension would require at least a cubic mile of water. Where could it have come from? The only possibility is that the heat of the approaching eruption might have melted a great mass of ice and so furnished the requisite water. To melt such an enormous block of ice would require a stupendous quantity of heat, but the energy of the erupting volcano was probably many times more than sufficient for this. The volcanoes are so heavily covered with glaciers that it is not improbable that there may be a cubic mile of ice on their drainage area. The trouble is that the volcanoes are still ice-clad at the present time. There is no indication of their having carried within recent geological time larger glaciers than those that still cover their flanks. They bear as many and as large glaciers as their inactive neighbors east and west. One of the remarkable features of the eruption was its small effect on the glaciers of the Volcanoes. There are two miles of ice cliff in the rim of Katmai crater, remnants of glaciers which were beheaded, but not melted, by the eruption. The remains of these glaciers cover every hollow in the mountain. The most extensive of them all stretches down into the Valley of Ten Thousand Smokes, where it meets the mud flow. Mageik, likewise, has a notable snowcap which extends up to and around


THE VALLEY OF TEN THOUSAND SMOKES
FROM SURVEY BY THE KATMAI EXPEDITION
OF THE NATIONAL GEOGRAPHIC SOCIETY
ROBERT F. GRIGGS DIRECTOR
TRIANGULATION AND TOPOGRAPHY BY C. F. MAYNARD
SCALE OF MILES
EDGE OF MUD FLOWS THUS
CERTAIN DEFINITE LOCATED FUMEROLES THUS
CONTOUR INTERVALS 200 FEET
155°20'
155°10'
155°
58°20'
58°10'
Needle Pk.
Ukak River
Knife Peak
VALLEY
OF
TEN THOUSAND
SMOKES
Buttress Mt.
Broken Mt.
Baked Mt.
Novarupta Vol.
Falling Mt.
Mt. Cerberus
Mt. Katmai
Crater Lake
Trident Vol.
Katmai Pass
Mageik Vol.
Mageik Creek
Observation Mt.
Katmai Mud Flow
Katmai River

the crater. Its glaciers are still, as Spurr described them, the most extensive in the district. Two of them come down into the Valley of Ten Thousand Smokes where their tips were apparently melted by the mud flow as it ran across them, but they show no sign of having otherwise contributed to it.

If the eruption had caused any wholesale melting of glaciers, not only should the bare hollows they formerly occupied be evident, but the water thus released should have caused tremendous floods on both sides of the range, for it is hardly conceivable that all of the ice melted could have been in a single locality, and that the whole of the water so formed could have been taken up by the mud. But the only floods, of which there is any evidence, occurred long after the eruption and were due to other causes.

HOT MUD FLOW MUST HAVE COME FROM INTERIOR OF THE EARTH.

Although it has been made clear that the mud could not well have come down from the mountains, one of the most important evidences of that fact has not yet been discussed. The high mud mark has been mentioned as one of the most conspicuous features of the Valley. It was clearly produced, like a high water mark, by the mud rising against the sides of the Valley. It would not be developed at any point where mud flowed into the Valley from the mountains above. It should, therefore, be easy to recognize the source of the mud by the absence of high mud marks at any point where it may have entered the Valley. But an examination of the circumference of the mud flow shows that the high mud mark is continuous, for it can be clearly followed around the whole of the mud flow, except in the vicinity of Novarupta Volcano, where the great thickness of the overlying ash deposit obscures the relation of the deeper layers. This can only mean that the mud welled up from within the Valley itself. (See map, page 138.)

Our search for its source had to be transferred, therefore, from the surrounding mountains to the Valley floor. The broad smooth floor of the Valley, although broken by the thousands of fissures and craters from which issue its millions of volcanoes, shows no orifices that give any particular evidence of having been the source of the mud. The only thing to guide us in our search was the slope of the high mud marks, for since the mud flowed down the valley under gravity it must have originated, in part at least, near the highest points that it covered.

PROBABLY ERUPTED FROM SEVERAL FISSURES.

From this fact it becomes at once evident that it could not have come from a single orifice, for there are two distinct summits from each of which it flowed in both directions. One of these is Katmai Pass, the other is in the vicinity of Novarupta Volcano. The altitude of both is in the neighborhood of 3,000 feet. From Katmai Pass the mud flow not only reaches into the Valley of Ten Thousand Smokes, but extends down the

Photograph by D. B. Church

PART OF THE MUD FLOW ACROSS THE PASS FROM THE VALLEY.
Looking toward Observation Mountain from the upper flat of Mageik Creek. The layers of Katmai ash covered by a secondary flow are plainly shown in the bluff, two-thirds of the way up.

valley of Mageik Creek to the foot of Observation Mountain, against which it accumulated to a thickness of 30 or 40 feet. (See picture above).

Novarupta, although situated in the floor of the Valley, is located near a col which separates the two arms of the Valley that encircle the Broken Mountains. On the west side of this col the surface of the mud flow descends till it joins the branch coming down from the Pass at an altitude of about 2300 feet, then continues its descent across the front of Cerberus and Mageik down the main valley to the terminus of the flow, a hundred feet above sea level. From the east side of the divide the mud flow slopes gently down around the foot, first of Mt. Katmai and then of Knife Peak, till it joins the main valley below the Broken Mountains.

It is clear that, so far as its gravitational relations are concerned, the mud flow could be accounted for by assuming two points of extrusion at these two summits, but the evidence furnishes no reason for excluding the participation of other vents at any point along the line of the flow. Around Novarupta the mud flow has the appearance of being extraordinarily massive, as though a great quantity of it had welled up from that vent. But the appearance of Katmai Pass gives the contrary impression, for there the depth of the flow is slight and there is nothing to indicate that there was ever any great accumulation at that point. Inasmuch as there is clear evidence of fumarole action since the eruption, on both sides of the Pass, it appears more probable that the mud in this vicinity welled out of a number of fissures at different levels, rather than from a single large vent at the summit.

There is no evidence of any of the specific vents from which the mud may have come. If, as is supposed, they were merely fissures in the floor of the Valley, lying below the level of the flow, one would not expect to find them any more than he can locate the unseen springs which feed many a lake. They may be the same as some of the fissures from which the Smokes of the Valley are at present issuing, or they may be stopped up with their own product, the present volcanoes coming from new fissures opened since the mud flow.

NO EVIDENCE THAT IT ORIGINATED IN EXPLOSIVE ACTION.

Since the mud resembles a fragmental product, it might be supposed that it originated in explosive action, but, however this may be, there is no evidence of explosions violent enough to have thrown it out against the mountains round about, for, as already pointed out, it is confined to the Valley. So far as there is evidence of its origin, therefore, the indications are that it welled quietly up out of the bowels of the earth.

It is clearly recognized that current theories of volcanic action do not provide any means of explaining the formation of any such mud flow as we have found in this Valley of Ten

Thousand Smokes. Nor have I any hypothesis to suggest to account for the mechanism of its formation. This has long held me back from reporting its occurrence. But the evidence that it actually did occur seems perfectly clear and conclusive. Under the circumstances, therefore, there was nothing to do but to report the facts as they were found in the field.

It is proper to add, however, that a reading of the descriptions of other eruptions, in the light of what we have found in the Valley of Ten Thousand Smokes, indicates that the extrusion of such masses of hot mud may not be so much a unique as a neglected aspect of volcanism. But a discussion of such phenomena lies beyond the scope of the present paper, which is concerned merely with recording the phenomena of the Valley of Ten Thousand Smokes.

In the discussion of this remarkable terrane we have set down numerous considerations which would be quite superfluous if it were located in a district more accessible to geologists, so absolutely clear are its major relations. But, recognizing that under present circumstances it would not be practicable for all geologists who might be skeptical to go and see it for themselves, we have tried to supply the answers to all the questions likely to arise in the minds of such skeptics. Since the district has been set aside as a National Monument, however, it is to be hoped that it will not for long remain so inaccessible, but that its remarkable features may be seen and studied by many other observers within a very few years.

KEY TO THE NEARCTIC SPECIES OF THE GENUS LAPHRIA (DIPTERA, ASILIDÆ).

By W. L. McAtee.

Working up material for a list of the Asilidæ of the District of Columbia region necessitated the present revision. The fact that it is necessary to describe as new, five species from this area, of a single genus of flies of as large average size as the Asilidæ, would indicate that there is still plenty of work for entomologists in the most frequented collecting grounds. Mr. Nathan Banks who is collaborating on the Asilid list has found it necessary to describe also one species each of *Leptogaster*, *Dioctria*, *Dasyllis* and *Asilus* from local collections.

In determining the status of our three described and five undescribed species of *Laphria*, it became desirable to see as much material as possible. For generous loans of specimens and other help the writer is indebted to Messrs. C. P. Alexander, Nathan Banks, W. S. Fisher, C. T. Greene, J. S. Hine, F. Knab, J. R. Malloch, and W. R. Walton. Professor J. M. Aldrich kindly furnished valuable bibliographic references. Of the species of *Laphria* listed by Aldrich,* *amanda* Walker (which appears to be a *Nusa*), *coerulea* Williston (now *willistoniana* Enderlein), *componens* Walker, *homopoda* Bellardi, *ichneumon* Osten Sacken, *marginalis* Williston, *numitor* Osten Sacken, *olbus* Walker, *ruficauda* Williston, and *triligata* Walker, so far as known, are entirely neotropical in distribution.

In the same list—a collection of 35 names in all—the following cases of synonymy occur: *bilineata* Walker = *gilva* Linneaus; *pubescens* Williston = *sadales* Walker; and *xanthippe* Williston = (Lampria) *felis* Osten Sacken. The list may be further reduced by the elimination of one preoccupied name, *anthrax* Williston, not Meigen = *carbonarius* Snow.

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* Aldrich, J. M., A Catalogue of North American Diptera, Smiths. Misc. Coll. Vol. 46, 1905, pp. 272–3.

In the purview of the present paper the following names remain unidentified: *aeatus* Walker (see discussion under *aimatis* n. sp. further on), *carolinensis* Schiner, *flavescens* Macquart, *flavipila* Macquart, *georgina* Wiedemann, *lasipes* Wiedemann, *melanogaster* Wiedemann (all black species have been disregarded, because only females have been seen) and *terrae-novae* Macquart. Excepting *aeatus, lasipes* and *melanogaster*, these species would appear to be of the *Dasyllis* type. After all eliminations (and two additions) there are considered in the present discussion the following previously named species of *Laphria: canis* Williston, *carbonarius* Snow, *disparella* Banks, *felis* Osten Sacken, *ferox* Williston, *franciscana* Bigot, *gilva* Linnaeus, *rapax* Osten Sacken, *sadales* Walker, *saffrana* Fabricius, *sericea* Say, *ventralis* Williston, *vivax* Williston and *vultur* Osten Sacken. Ten new species are described, viz.: *aimatis aktis, coquillettii, index, ithypyga, janus, sicula, scorpio, trux*, and *winnemana*.

Arrangement of the species of *Laphria* to indicate relationships is attended with the difficulty usual to such endeavors. The linear series to which we are reduced by the limitations of printed pages, is unsatisfactory. A sphere is a better figure to accommodate our conception of the origin and relationships of the members of any evolutionary group. The hypothetical ancestry is at the center, while descendants occupy positions in various directions and at varying distances from the center according to the line of their specialization and the degree of their departure from the type. Closely related forms may be ranged side by side, but relationships of any degree between forms wherever located may be indicated by the lines which conceivably may connect any points in such a figure.

Though it would be possible to construct a model embodying a conception of this nature, and even to reproduce it in a fairly satisfactory way by photography, as a rule such a concept will be mental only. Since practical considerations demand a linear arrangement, one for the species of *Laphria* examined by the writer is submitted, though not without misgivings. While other features have been given some consideration, the characters of the male hypopygium have had preponderant weight in governing the arrangement. Increasing use of genital characters is a conspicuous tendency of modern taxonomic entomology, nevertheless it must be admitted that the significance of these characters is not thoroughly understood. Sexual polymorphism is well known in the Lepidoptera. In another group of Arthropoda, the Crustacea, and particularly in crawfishes, the same phenomenon occurs, and in this case differences in type extend to the male genitalia.

We do not know whether comprehensive life-history investigations, especially rearing prolonged to several generations, will vitiate some of the classification based on genital characters, but until such researches have been made we can only proceed upon the basis of observed differences. Meanwhile confidence in the method is inspired by discovery of correlations of other characters with those of the genitalia, and especially by the disclosure among specimens sorted on the basis of genital structure, of previously unnoticed differences in other significant details.

For the sake of ease of observation only the external structure of the male hypopygia has been used in the present study. When it is necessary to refine the classification of the nearctic *Laphria*, undoubtedly additional useful characters may be found in the hooks, claspers and other more hidden details of the genitalia.*

The present revision comprises 23 species of which 10 are described as new and 9 varieties of which 5 are here first characterized. On the basis of this experience the writer would expect new forms among every considerable collection of flies on the genus *Laphria*.

In the following arrangement, groups of species are separated by spaces; looseness of relationship within groups is indicated by bracketing individually the comparatively less related species, and closer kinship by bracketing in pairs the nearer relatives.

* The terminology employed for the parts of the hypopygia is that learned by the writer in the study of homoptera, especially the Psyllidæ. That portion of the hypopygium bearing the forceps is the genital valve; the opposed portion, the anal valve. For details of these structures see an article by R. E. Snodgrass, entitled "The inverted hypopygium of Dasyllis and Laphria." (Psyche. 9, Oct., 1902, pp. 399-400, Pl. 5). It may be said the "inversion" in *Laphria* is of rather fortuitous occurrence. Recently emerged specimens have the hypopygium in normal position, with genital valve opposed to lower surface of abdomen, as seen in Dolichopodidæ, etc. All degrees of rotation of the hypopygium occur, and apparently, copulation, ending in a tail to tail position of the flies, has much to do with the inversion.

vultur
{sericea
{aktis
janus

ferox

{gilva
{vivax
{ventralis
{coquillettii

trux

aimatis

sadales
felis

scorpio

index
ithypyga

{sicula
{franciscana

{canis
{winnemana

saffrana

So far as specialization of the hypopygium goes, an extreme degree in certain directions is exemplified by *vultur*, by *ferox*, *gilva*, *scorpio* and *canis*. Yet these species are not related to each other and cannot be placed together at the apex of an evolutionary series. Evolution is a matter of radiation, and in a linear series this fact forces a wave conception, proceeding from a low degree of specialization along a certain line to its culmination, dropping to the low point of a different line, and so on.

In the foregoing arrangement *sadales* and *felis* occupy the high point with reference to length of third antennal joint, it being nearly three times length of basal joint; in all the other species it is almost exactly twice that length. This is a character possessed by some species of *Lampria*, and if *Lampria* were incorporated into the genus *Laphria* this would be its position—among species which agree in every essential except in possession of spinose hind femora.

This latter character exists in varying degree and probably there is a complete intergradation between the genera in this respect. In some specimens of *Lampria rubriventris*, the tubercles are evanescent. However, the genus *Laphria* is so large (more than 300 described species) that it is not desirable to merge with it separable groups even if absolutely trenchant characters are not available.

The same argument applies in the case of the species grouped under *Dasyllis*. Professor M. Bezzi has pointed out* the lack of definitely separating characters between *Dasyllis* and *Laphria*, but it must be admitted that *Dasyllis* has a typical general appearance different from most species of *Laphria*, and that the male genitalia are of a different type (see Figs. 24 and 25). According to the opinion of Col. J. E. Yerbury, cited by Dr. S. W. Williston,† there is but one species of *Dasyllis*, the type species, *Laphria haemorrhoa* Wiedemann. Not having seen this species, I am unable to comment on the case.

Nusa should be regarded as a genus distinct from *Laphria*, not on the usually cited character of decided narrowing or closure of the first posterior cell, which is illusory, but on the grounds of a distinct type of genitalia (in which body of the forceps is simple, but one or both sets of claspers are exposed, taking the position of the apex of the forceps in *Laphria*, (see Fig. 26), and upon habitus, an important feature of which is the full set of thoracic markings, including three pairs of lateral lunules. Many of the species have also swollen femora and curved tibiæ.

Key to the Males of Nearctic Species of Laphria Based Chiefly on Characters of the Genitalia.

a. Forceps comparatively slender, nearly straight when viewed from above (except in *aktis*, Fig. 3), with a falcate process forming part of outer lateral surface.
 b. Forceps somewhat spatulate, and nearly straight when viewed from above.
  c. Falcate process rather broad and blunt (Fig. 4); pale (golden) pubescence most conspicuous on posterior half of thoracic dorsum....*janus* n. sp.
  cc. Falcate process more slender and acute.
   d. Forceps, viewed from side, decurved at tip (Fig. 1); general pubescence reddish tawny..*vultur* OS.
   dd. Forceps not decurved at tip (Fig. 2); general pubescence golden.... ....*sericea* Say
 bb. Forceps not spatulate, curved when viewed from above; falcate process very slender and acute (Figs. 3, 3a); general pubescence golden....*aktis* n. sp.

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* Zeitschr. f. syst. Hym. u. Dipt. VII, 2, March 1, 1908, pp. 108-110.
† Manual of North American Diptera. Third Ed. 1908, p. 389.

aa. Forceps stouter, and more or less curved when viewed from above (except in *saffrana*, Fig. 23), without lateral falcate process.

e. Each forceps bearing on median upper surface a lamellate process apparently formed of coalescent bristles.

f. This process very long, fimbriate and brush-like, unaccompanied by a smaller inner apical process (Fig. 5); dark species with golden pile on face and posterior margins of abdominal segments... .... *ferox* Will.

ff. Median process less brush-like, and accompanied by a smaller one of more or less similar structure on apical part of inner margin of forceps.

g. The two processes almost contiguous at base, both well-elevated distally above surface of forceps, main process about as broad apically as eleswhere (Fig. 6); abdominal segments 4–6 in part ferruginous with concolorous pile................. *gilva* L.

gg. The two processes more remote at base; the smaller rather closely paralleling surface of forceps.

h. Main process as broad or broader at tip than elsewhere.

i. Median lamella less solidified; inner process not extending beyond end of forceps (Fig. 7); pale pile, light yellowish green to pale golden, not forming distinct bands clear across hind margins of abdominal segments.... *vivax* Will.

ii. Median lamella more solidified; inner process extending slightly beyond end of forceps (Fig. 8); pale pile, golden to red gold in color, forming conspicuous bands across hind margins of segments.................. *vivax anthemon* n. subsp.

hh. Main process narrowed apically (Figs. 9, 10); yellow pile on posterior half of pronotum.

j. Segments 3–7 with hind angles and margins ferruginous with golden pile............................ *ventralis* Will.

jj Segments 3–7 entirely ferruginous with concolorous hair.. .... *coquillettii* n. sp.

ee. Forceps without median lamellate process.

k. Each forceps with a more or less distinctly separate process on apical part of inner margin.

l. Process rather closely paralleling body of forceps.

m. Process, as seen from side, clearly though sometimes only slightly separated from body of forceps.

n. Larger species with dense ferruginous pile on abdomen.

o. Apical process of forceps distinctly curved, somewhat twisted longitudinally, and rather abruptly narrowed near tip (Fig. 11); species with whitish hair on posterior half of pronotum; segments 3–7 with dense golden to orange red hair.

p. Length over 25 mm.; abdominal pile orange red .... *trux* n. sp.

pp. Length under 20 mm.; abdominal pile golden. .... *trux* var. *audax* n. var.

oo. Apical process of forceps neither curved nor twisted (Fig. 12); segments 3–7 in part ferruginous with concolorous pile. . *aimatis* n. sp.

nn. Smaller species; abdomen nearly bare or with only a moderate proportion of dense (usually golden) pubescence.

q. Forceps as in Figure 13; blackish species, with legs, except tarsi, reddish yellow. .... *sadales* walk.

qq. Apical process of forceps a little longer, more pointed and farther recurrent along inner margin of forceps (Fig. 14); abdominal segments 2 or 3 to 7 yellow to reddish. (For key to varieties see p. 162). . *felis* OS.

ll. Process not paralleling forceps, either almost touching apex of forceps or widely separate therefrom.

r. Process almost touching apex of forceps, distinctly longitudinally twisted; a deeply emarginate lobe on inner side of forceps at base of process (Fig. 16); facial pile silvery to yellow; no golden triangle on thorax; considerable golden pile on abdomen.......... *scorpio* n. sp.

rr. Apical process not longitudinally twisted, well separated from body of forceps, the latter therefore appearing distinctly emarginate; species with narrow triangle of golden pile on thorax and golden pubescence on abdomen.

s. Process and apex of forceps appearing like an opposed index finger and thumb, the enclosed emargination, deep and narrowest distally; hypopygium more oblique (Fig. 17)......... *index* n. sp.

ss. Emargination more shallow, widest distally, the apical process enlarged so that it has become main body of forceps; hypopygium straighter (Fig. 18)..................... *ilhypyga* n. sp.

k. Forceps without inner apical process.

t. Forceps concave along inner margin, without strong lobe at about middle of its length.

u. Forceps viewed from above, narrowed to apex.

v. Forceps rather acute, only slightly hollowed out beneath at apex. (Fig. 19).......... *sicula* n. sp.

vv. Forceps less acute slightly upturned exteriorly at apex; much hollowed out beneath, with a thin, vertical plate along concave inner margin near apex. (Fig. 21)................. *canis* Will.

uu. Forceps more or less clavate at apex; well hollowed out beneath.

w. Apex of forceps trapeziform (Fig. 22).... *winnemana* n. sp.

ww. Apex of forceps spoon-shaped (Fig. 20).... *franciscana* Bigot

tt. Forceps essentially straight, with a large inwardly and downwardly projecting lobe at about middle of its length (Fig. 23); species with disk of thorax black except for two central golden spots.. *saffrana* Fabr.

Key to the Nearctic Species of Laphria Based So Far As Practicable Upon Coloration.

a. Disk of thoracic dorsum black except for a central pair of yellow spots; general color of pubescence old gold................................ *saffrana* Fabr.

aa. Coloration otherwise.

b. Integument of abdomen with yellow to ferruginous areas, bearing dense concolorous pubescence.

c. Median parts of segments so colored.
d. Segments 3 (or 2) to 7 in part ferruginous with concolorous hair.... .... *aimatis* n. sp.
dd. Segments 4–6 in part so colored.......... *gilva* L.
cc. Hind angles and margins or entire segments so colored.
e. Hind angles and margins of segments 3–7 yellow.......... *ventralis* Will.
ee. All of segments 3–7 yellow; dense patch of yellow hair on posterior half of pronotum.......... *coquillettii* n. sp.
bb. Abdomen black in ground color, or if partly red, these areas not bearing dense concolorous hair.
f. First 3 segments strongly contrasting with others either in color of pile or integument.
g. First 3 segments black, others yellowish to reddish with sparse pubescence. (For key to varieties see page 162)..... *felis* OS.
gg. Same coloration, but segments 4–7 with dense yellowish to reddish pile.
h. Patch of whitish pile on posterior half of pronotum... *trux* n. sp.
hh. Without such a patch.......... *carbonarius* Snow
ff. Color of first 3 segments not strongly contrasting with that of others.
i. Legs reddish, body black, nearly bare.......... *sadales* Walk.
ii. Legs dark.
j. With copious bright golden to ardent rufous pile over whole dorsum of thorax and abdomen.
k. All hair of head including mystax reddish tawny, concolorous with that of remainder of body.... *vultur* OS.
kk. Hair of head in part black.
l. Male genitalia as in Figure 3.......... *aktis* n. sp.
ll. Male genitalia as in Figure 2.......... *sericea* Say
jj. Pile of thoracic dorsum black, at least, at the sides in front.
n. Pale pile extending forward, at least to middle of pronotum, forming a distinct narrow triangle.
o. Male genitalia as in Figure 17.......... *index* n. sp.
oo. Male genitalia as in Figure 18...... *ithypyga* n. sp.
nn. Pale pile not forming a distinct narrow triangle.
p. Pale pile covering at least posterior half of pronotum.......... *janus* n. sp.
pp. Pale pile covering less than half of pronotum usually merely fringing posterior part.
q. Species with some dense yellowish to golden pile on abdomen.
r. Slender species.
s. Male genitalia as in Figure 16...... .... *scorpio* n. sp.
ss. Male genitalia as in Figure 21...... ..... *canis* Will. var. *disparella* Banks.
rr. Robust species.
t. Tufts of hair in front of wings and halteres yellow.......... *vivax* Will.
tt. Tufts of hair in front of wings and halteres black.......... *ferox* Will.
qq. Species with no more than scattering yellow hairs on abdomen.
u. Male genitalia as in Figure 19... .... *sicula* n. sp.
uu. Male genitalia as in Figure 20... .... *franciscana* Bigot
uuu. Male genitalia as in Figure 21... .... *canis* var. *canis* Will.
uuuu. Male genitalia as in Figure 22... .... *winnemana* n. sp.

Laphria vultur Osten Sacken.

Laphria vultur, Osten Sacken, C. R. Western Diptera; descriptions of new genera and species of Diptera from the region west of the Mississippi and especially from California. Bul. U. S. Geol. and Geogr. Survey of the Territories, III, 1877, p. 286. (Woods of the Coast Range above Santa Cruz, Calif.; Webber Lake, Sierra Nevada.)

A large black* species with copious yellowish-red to reddish-orange hair; mystax and pleural hair lightest in color, that of abdomen most intense. Wings fumose, interior of cells more hyaline. Male forceps long, decurved near tip where there is a deflexed lobe on each side; falcate process long and rather acute. (Fig. 1). Length, 22–28 mm.

Localities represented: Kaslo, B. C., May 30, June 5, H. G. Dyar; July 15, R. P. Currie, (U. S. N. M.)†; Ainsworth, B. C., July 11, 1903, in cop., R. P. Currie, (U. S. N. M.); Bear Lake, B. C., July 21, 1903, J. W. Cockle, (U. S. N. M.); Fry Creek, B. C., July 23, 1903, in cop. H. G. Dyar, (U. S. N. M.); Victoria, B. C., July 17, 1901, (Hine); Goldstream, B. C., Aug. 10, 1902, (Hine); Washington, Kincaid, (Ill. State Lab.); Mt. Hood, Ore., H. K. Morrison, (U. S. N. M.); Yellowstone Park, June 26, 1907, W. Robinson (U. S. N. M.); North Cheyenne Canyon, El Paso Co., Colo., July 2, 1914, Champlain, (U. S. N. M.).

Laphria sericea Say.

Laphria sericea Say, Thomas. American Entomology, 1, 1824, pp. 12–13, Pl. 6, (United States). The Complete Writings of Thomas Say on the Entomology of North America. 1, 1859, pp. 12–13.

A black species with yellowish golden to ardent red gold hair on upper surface of thorax and abdomen. Beard, deflexed pile on face, hair on coxæ and lower pleural plates and tuft under root of wing whitish in female, tawny in male; bristles of mystax, tufts of hair on neck, vertex, and just below margin of thoracic dorsum, and sometimes short pile on anterior disk of thorax black. Hair of legs black, mixed with white, especially on posterior surfaces. Wings clear to blackish hyaline. Forceps of male genitalia, long, slender; deflexed lobes less prominent than in *vultur* and falcate process shorter. (Fig. 2). Length 16–25 mm.

A female specimen from White Mts., Vt., Geo. Dimmock (M. C. Z.) which is referred to here differs in having the thoracic dorsum clothed with pale yellowish pile.

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* Unless otherwise stated, the ground color throughout of species described in this paper is black.

† Abbreviations following data indicate collections in which the specimens now are deposited. In full these collections are those of W. S. Fisher, J. S. Hine, Illinois State Laboratory of Natural History, Museum of Comparative Zoology, University of Kansas, United States Biological Survey, United States National Museum and W. R. Walton.

Other localities represented: Mt. Tom, Mass., July, Morrison, (U. S. N. M.); Ithaca, N. Y., July 25, 1893, June 15, 1895, (Hine); Medina, Ohio, June 12, 1899, (Hine); Vinton, Ohio, June 5–12, 1900, June 19–22, 1901, (Hine); Ira, Ohio, (Hine); Cincinnati, Ohio, May 30–31, 1910, (Hine); Algonquin, Ill., June 7, 13, 1895, (Ill. State Lab. Nat. Hist.); Inglenook, Pa., June 20, 1909, May 30, 1912, June 27, 1912, June 12, 1913, in cop., Champlain; June 26, Kirk; May 28, 1911, May 27, 1912, W. S. Fisher (Walton); Inglenook, Pa., June 14, 1913, June 14, 22, 1917, W. S. Fisher (Fisher); Harrisburg, Pa., July 5, 1908, W. R. Walton, (Walton); Enola, Pa., June 6, Kirk and Champlain, (Walton); Heckton Mills, Pa., June 15, 1909, W. R. Walton, (Walton); Perdix, Pa., May 27, 1911, W. S. Fisher, (Walton); Corry, Pa., W. R. Walton, (Walton); Rockville, Pa., July 8, 25, 1912, Champlain, (Walton); Cupid's Bower Id., Md., May 31, 1915, R. C. Shannon, (U. S. N. M.); Great Falls, Va., May 26, 1914, R. P. Currie, (U. S. N. M.); Great Falls, Va., June 16, 1910, R. A. Cushman, June 5, 1917, C. T. Greene, (U. S. N. M.); Scott's Run, Va., June 2, 1912, W. D. Appel (Biol. Survey); Dead Run, Va., June 9, 1915, R. C. Shannon, (U. S. N. M.), feeding on *Nicagus obscurus;* Falls Church, Va., June 12, 1916, J. N. Knull, (U. S. N. M.); Giles Co., Va., W. M. Davis, (U. S. N. M.); North Fork, Swannanoa River, Black Mt., N. C., May, N. Banks, (M. C. Z.); North Carolina, (U. S. N. M.); Florida, (U. S. N. M.).

Laphria aktis new species.

In most respects a miniature of *L. sericea.* The beard and hair on coxæ are paler, however, even in the males. The forceps of the male genitalia are relatively shorter, distinctly curved and the falcate process is much longer, and very sharp pointed. (Figs. 3, 3a). Females are separable, if at all, on the basis of size. Length, 13–22 mm.

Type, male from Inglenook, Pa., June 27, 1912, Champlain (Walton).

Other specimens examined: Loudonville, Ohio, June 6, 1915, (Hine); Ira, Ohio, (Hine); Perdix, Pa., May 27, 1911, W. S. Fisher, (Walton); Heckton Mills, Pa., May 31, 1909, W. R. Walton, (Walton); Inglenook, Pa., May 30, 1912, Champlain, (Walton); June 14, 22, 1917, W. S. Fisher, (Fisher); Great Falls, Va., May 25, N. Banks, (M. C. Z.); North Carolina, (U. S. N. M.).

Laphria janus new species.

A species which appears to have the posterior half of thorax densely yellowish haired and the anterior half sparsely blackish. Under the microscope, however, when the insect is viewed from the front it is evident that much of the pile on anterior half of thorax is golden. It is nearly erect, however, so that in examining the insect from above one looks down between the hairs at the dark integument of the thorax. These erect hairs have black ones scattered among them. The pile on posterior half of thorax is longer and more recumbent and varies in color from pale yellow (sometimes almost white) to bright golden.

Beard, mystax, except for a few black hairs below, hair on coxæ, and pleuræ pale yellowish. Hair on abdomen semi-erect, sparse and pale yellow anteriorly, becoming more recumbent, dense and ferruginous posteriorly. Black hair on legs (accompanied by some pale ones, and the usual short, dense, rusty pile on inner side of front tibiæ and tarsi), vertex, occiput, neck tubercle, tuft in front of wing (sometimes yellow) fringe about thorax and sparsely on anterior half as above described.

Long yellowish to reddish hair on genitalia; anal valve moderately swollen; forceps, see Figure 4. Wings brownish hyaline; center of cells sometimes clear. Length, 15–20 mm.

This form is identified in some collections as *L. terræ-novæ* Macquart, but it does not closely agree with the description.* For instance, "underside of head with black hairs" and "abdomen with pale yellowish gray hairs" do not fit the present species. Even if the description of *terræ-novæ* were a much better fit, I should prefer to use a new name, since neither type nor homotype are available for comparison.

Western specimens differ slightly in general appearance from eastern ones, the color of hair on abdomen averaging more ardent and the tuft of hair in front of root of wing being more often wholly yellow.

Type specimen, male, and allotype, female, from near summit of Mt. Washington, New Hampshire, George Dimmock. In collection of U. S. National Museum.

Other specimens examined: Mt. Washington, N. H., George Dimmock, (U. S. N. M., M. C. Z.); June 29, 1874; H. K. Morrison, (U. S. N. M.); White Mts., N. H., George

* Macquart, J. Dipteres exotiques, noveaux ou peu connus, 1, Part 2, 1838, pp. 69–70.

Dimmock, (M. C. Z.); Morrison, (U. S. N. M.); New Hampshire, Ottolengui, (U. S. N. M.); Maine, (U. S. N. M.); Isle Royale, Mich., July 26, 1905, (Hine); Dickinson County, Mich., July 6, 1909, Michigan Biological Survey, (Hine); Heyden, Ontario, July 31, 1906, E. B. Williamson, (Hine); Sault Ste. Marie, Ont., (Hine); Creede, Colo., Aug., 1914, 8844 feet elevation, S. J. Hunter, (Hine); Tolland, Colo., Aug. 15-16, 1917, E. C. Jackson, (Biol. Survey); Washington, Brodie, (U. S. N. M.); Kaslo, B. C., June 12, 18, R. P. Currie, July 11, 1903, A. N. Caudell, (U. S. N. M.).

There is considerable resemblance between the females of this species and those of *Dasyllis fernaldi* Back. The latter may be distinguished however by the erect position of pile on posterior part of thorax, the greater abundance and entirely yellow color of pleural pile and more copious yellow hair on tibiæ. Males of this species of *Dasyllis* may be recognized by the characteristic form of genital forceps, (Fig. 24).

Laphria ferox Williston.

Laphria ferox Williston, S. W. On the North American Asilidæ (Dasypogoninæ, Laphrinæ), with a new genus of Syrphidæ. Trans. Am. Ent. Soc. 11, Dec., 1883, pp. 29–30 (Washington Territory).

This species was originally characterized from females only and knowledge of males now calls for some alteration of the description.

Vestiture black, except for beard, coxal hairs, part of the hairs on posterior part of thorax, all of which vary from whitish to golden. Pubescence of abdomen yellow to reddish golden, more dense on hind margins of segments and upon posterior and anterior segments, except in males in which the pale pubescence is confined to first four segments and posterior margins of others, the remaining hair being black. Wings blackish hyaline to smoky. The male genitalia of this species bear the most remarkable appendage of any of the genus seen by the writer. This is a single, median, brush-like process of each forceps which is broad, about half as long as the process, oblique and fimbriate at apex. It seems distinctly a lamella composed of coalesced bristles, which are separate toward the apex, but solidly fused near base. (Fig. 5). Length, 15–22 mm.

Specimens examined: Grouse Mt., Vancouver, B. C., July 1, 1904, (Hine); Victoria, B. C., July 20, 1902, (Hine); Hoquiam, Wash., Sept. 4, 1903, H. E. Burke, Homotype, (U. S. N. M.); Evaro, Mont., May 4, 1913, L. O. Swartz, (U. S. N. M.).

Laphria gilva Linnaeus.

Asilus gilvus Linnæus, C. Systema Naturæ per regna tria naturæ secundum ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Ed. 10, 1758, genus 227, species 6 (Europe).

This species, the only one in the Genus *Laphria* known to be common to Europe and North America, was originally described in the Fauna Suecica, but it is unnecessary to give a citation prior to the tenth edition of the Systema Naturæ, the point of beginning of all modern zoological nomenclature. The very brief original characterization of the kind upon which Linnaeus prided himself, is entirely inadequate for recognition of a species of *Laphria*. I am satisfied of the identity of the North American and European forms of this complex, only because of the very detailed description, especially of the male genitalia, by Dr. William Lundbeck in the Diptera Danica.*

Laphria bilineata "Barnston's mss." Walker, Francis. List of the specimens of Dipterous Insects in the collection of the British Museum. 4, 1849, p. 1156. (St. Martin's Falls, Albany River, Hudson's Bay).

It is probable that this name is a synonym of *gilva*. Walker states: "Each segment from the third to the fifth adorned with a large triangular ferruginous spot, which is clothed with bright tawny hairs." Only two species of the general aspect of *gilva* are thus far known from the Nearctic region and one of those (*L. aimatis* n. sp.) has segments six and seven involved in the ferruginous area.

Description: Mystax black; surface above and at sides of facial prominence, silvery pruinose, and bearing decumbent silvery pile; beard silvery; hair of occiput mixed black and whitish. Disk of thorax with the following grayish pruinose markings; a longitudinally divided median vitta, and two lateral elliptical areas, rather acute posteriorly. Pile of thorax, fine, rather erect, mixed black and whitish. Bristles on sides of thorax and edge of scutellum black. First three abdominal segments and part of fourth with white pile, long and conspicuous at sides. Remainder of abdomen with rather recumbent pile, black except upon a median spot (of varying shape) upon segments 4–6, where the integument as well as the pile is ferruginous to golden. Traces of this pile occur in some specimens upon the segments 3 and 7. Legs with long black bristles, and long soft black and whitish hairs, those of coxæ, undersides of legs in general and of venter whitish. Wings smoky hyaline, clearer toward base. Male forceps, each with two lamellate appendages, of which one is median, broad (about equally

* Lundbeck, William. Diptera Danica, Genera and species of flies hitherto found in Denmark 2, 1908, pp. 49–51.

so throughout), well elevated, and about half as long as hypopygium, and the other lying on the inner side, narrower, somewhat curved and not so much elevated. (Fig. 6). Length 16–20 mm.

This species is most easily separated from *L. aimatis* n. sp. by the essentially black seventh segment.

Specimens examined: Tyngsboro, Mass., Blanchard, (U. S. N. M., M. C. Z.); Dedham, Mass., (U. S. N. M.); Beverly, Mass., Burgess, (U. S. N. M.); Massachusetts, (M. C. Z.); Alpena, Mich., Wm. A. Nason, (Ill. State Lab.); Dickinson Co., Mich., July 27, 1909, (Hine); Sault Ste. Marie, Ont., (Hine); Whitefish Point, Lake Superior, H. G. Hubbard, (U. S. N. M.); Empire, Colo., August, J. D. Putnam, (M. C. Z.); Estes Park, Colo., August, 1892, F. H. Snow, (K. U.); Lame Deer, Mont., (U. S. N. M.).

Laphria vivax Williston.

Laphria vivax Williston, S. W. Trans. Am. Ent. Soc. 11, Dec., 1883, p. 30. (Washington Territory.)

Ground color shining black. Mystax black; decumbent pile on face, beard, pile of tibiæ decreasing in amount on posterior pairs, pile of pleuræ and periphery of thorax, scutellum and abdomen, more abundant posteriorly and on sides and hind margins of segments, light greenish yellow to pale golden. Pile of occiput mixed with black, and short nearly erect pile on disk of thorax black. Hair on coxæ pale golden, on femora mixed black and golden. Wings fumose hyaline, veins reddish. Male forceps with median brush like lamella and narrower curved, inner process not reaching end of forceps. (Fig. 7). Length 14–20 mm.

Specimens examined: Wellington, B. C., (Hine); Summit Co., Colo., T. D. A. Cockerell, (U. S. N. M.); Marshall Pass, Colo., Aug. 12, 1914, (U. S. N. M.).

Laphria vivax anthemon new subspecies.

A male from the top of Las Vegas Range, New Mexico, 11,000 feet, W. P. Cockerell.

Differs from the typical form in having the median lamella of forceps more solidified, the inner process projecting beyond end of forceps, (Fig. 8) and the vestiture in general more highly colored. The facial pile, beard and pile of abdomen are bright golden and thoracic fringes and tibial hair red gold. On account of the more intense color of the abdominal pile, this appears denser than in *vivax* and as it is most abundant along posterior margins of segments, gives the insect a more distinctly banded appearance. Wing veins more distinctly reddish. Length, 18 mm.

One specimen, the type, data given above, (U. S. N. M.).

Laphria ventralis Williston.

Laphria ventralis Williston, S. W. On the North American Asilidæ (Part 2). Trans. Am. Ent. Soc. 12, 1885, p. 55. (California.)

Mystax with only a few black bristles; remainder of mystax, facial pile, beard, coxal hair, thoracic fringes, pile and bristles of scutellum, and pile of abdomen light golden. On the sides of each segment from 3 to 7 the integument itself is ferruginous; posteriorly these spots are connected across hind margins of segments. The pile of abdomen is so arranged that viewed from above it appears most dense on sides and posterior parts of segments. Short, sparse, rather erect hair of thoracic disk pale golden, but in some lights appearing dark. Hair of legs mostly dark above, pale golden beneath. Wings smoky, veins reddish. Length, 18–20 mm.

In the male the mystax is wholly pale; and it as well as some of the remaining vestiture of the body, particularly the thoracic fringes, have a more ardent reddish gold color. The pile of thoracic disk is longer and more highly colored. The hypopygium is ferruginous with its various processes black. Lamellæ well solidified, median somewhat narrowed toward apex; inner much narrowed; both slightly upturned apically. (Fig. 9).

Specimens examined: Shasta District, Calif., July 1875, (M. C. Z.); Siskiyou, Calif., Aug. 7, (U. S. N. M.); Western Washington Territory, H. K. Morrison, (U. S. N. M.); Olympia, Wash., Sept. 24, Kincaid, (Ill. State Lab.)

Laphria coquillettii new species.

Mystax and beard, pale golden in male; mixed black and pale golden in female. Hairs of occiput, upper pleuræ, and copious short black, nearly erect pile of anterior half of thorax black. Tuft of hair in front of halteres, scutellar bristles and coxal hair, pale golden. Posterior half of thorax and scutellum densely covered with long, recumbent golden hair. Ground color of first two and most of the third segment of abdomen black, semi-erect pubescence pale golden; of remainder of abdomen ferruginous to chestnut brown, pile more dense and recumbent, golden to red gold in color. Legs with mixed black and very pale golden hairs. Wings smoky, somewhat lighter toward base. Hypopygium ferruginous, process black; much like that of ventralis. (Fig. 10). Length 15–20 mm.

Type a male, Los Angeles Co., Calif., Coquillett, (U. S. N. M.). Allotype and paratype males, Switzers' Trail, 3,500 feet, San Gabriel Mts., Calif., June 11, 1910, F. Grinnell, (Hine).

Named in honor of the collector, the late D. W. Coquillett, an entomologist who contributed to knowledge of the Asilidæ, and did much good work among Diptera in general.

Laphria trux new species.

Mystax golden; beard, coxal hair and tufts before halteres yellowish-white. Pile of occiput, thorax in general, most of the first three segments of abdomen, hypopygium and legs in general black. The legs have some yellowish white hairs especially beneath and the usual short velvety ferruginous pile inside front tibiæ and tarsi. The scutellum and a several times larger patch on thorax just in front of it are covered with long, recumbent slightly yellowish white hairs. Nearly half of the third segment and all of the remaining upper surface of abdomen is densely covered with close-lying orange-red pile. The integument is black. Wings brownish, some of the cells clearer within. Hypopygium large, of a very inflated and oblique type; inner apical process, striate, narrowed, curved, longitudinally twisted and slightly elevated toward apex, (Figs 11, 11a). A tuft of 4 strong bristles arising near base of this process forcibly suggests the origin of the median lamella seen on the forceps of some other species of *Laphria*. Length 27 mm.

The above is the description of a male from Los Angeles Co., Calif., Coquillett, (U. S. N. M.), Type.

A male about 25 mm. in length, collected on Switzer's Trial, 3,500 feet, San Gabriel Mts., Calif., by F. Grinnell (Hine) has the beard and coxal hair more grayish white, the mystax a little paler, with a few black hairs below, the tufts in front of halteres black and the recumbent hair on thorax and scutellum glistening white. For the present I place this in the species above described.

The latter specimen is a step in some directions toward *Laphria rapax* Osten Sacken,* but neither it nor the type of *L. trux* have whitish pile on face and first two abdominal segments, nor hair under antennæ altogether black, as stated in the original description of *rapax*.

The material I have seen suggests that there may be a series of species or at least subspecies of this group in California. The elucidation of this problem, together with that of the true status of *L. carbonarius* Snow (discussed below) would be an interesting study for some one who can do considerable field work in the area concerned.

Laphria trux var. **audax** new variety.

Differs from *trux*, in smaller size (18 mm.), hair in front of halteres and a few in lower part of mystax being black, and pale pile of thorax being glistening white and of abdomen golden.

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* See copy of original description farther on, p. 159.

Type, male, from San Bernardino Co., Calif., Coquillett, (U. S. N. M.). Paratype, male, Los Angeles Co., Calif., Coquillett, (U. S. N. M.).

Laphria rapax Osten Sacken.

Copy of original description:

"*Laphria rapax* n. sp. ♂ Head, posterior part of the thorax and two first abdominal segments with whitish, the remainder of the abdomen except the genitals, with ardent rufous pile; legs black. Length 20 mm. The lower part of the head and base of the proboscis beset with whitish pile; face likewise, but many, black, erect hairs are mixed with the white ones; hair under the antennæ altogether black. Front part of the thoracic dorsum with short black pile; the hind part with longer, semi-recumbent, whitish pile; scutellum with some whitish pile; male forceps very large; wings as usual brownish on the discal half and hyaline on the proximal. Hab.—Webber Lake, Sierra Nevada, July 28. A single male."*

Laphria carbonarius Snow.

Laphria carbonarius nom. nov. Williston, Ms. Laphria anthrax Williston (nec Meigen). Snow, W. A. List of Asilidæ, supplementary to Osten Sacken's Catalogue of North American Diptera. 1878–1895. Kansas University Quarterly 4, No. 2, Oct. 1895, p. 181.

Laphria anthrax Williston, S. W. Trans. Am. Ent. Soc. 11, 1884, p. 29. (Northern California.)

Copy of original description:

"*Laphria anthrax* n. sp. Female—Black, head, thorax, legs, and first two segments of the abdomen wholly black pilose; remainder of the abdomen, except the extreme tip, densely clothed with close-lying bright yellowish-red pile. Wings blackish. Length, 21 mm.

"The pile of the face is abundant, on the lower part composed mostly of bristles. Dorsum of thorax shining, wholly covered with short black pile, except the short black bristles above the wing. The third–seventh segments of the abdomen are wholly concealed beneath bright orange-red pile; the pile lies very closely and thickly. Tip of abdomen and venter black pilose. Legs wholly black pilose. Wings dark brownish or blackish; the anal and second basal cells in large part hyaline; the middle of the fourth and fifth posterior cells lighter.

"One specimen, Northern California (O. T. Baron).

"This species must resemble *L. rapax* O. S., and it is possible it may be the other sex, but the entire lack of white pile renders such a view improbable."

* Osten Sacken, C. R. Western Diptera. Bul. U. S. Geol. & Geogr. Survey Terr. 3, 1877, p. 286.

Four females are at hand which agree fairly well with the above description. Williston lays stress on *entire* lack of white pile, but a homotype (as well as the other three specimens), shows some fine white pile on posterior part of thorax on scutellum and on third segment, a row across posterior part of segment being particularly noticeable. In one specimen this row of hairs is orange red. Length 18-22 mm.

Specimens examined: Los Angeles Co., Calif., Coquillett, two females, one a homotype, (U. S. N. M.); Switzer's Trail, 3,500 feet, San Gabriel Mts., Calif., June 11, 22, 1910, F. Grinnell, (Hine).

There is a very strong probability that *L. carbonarius* is based on females of one or all the species of the *rapax* group. Only males of the latter are known, and only females of *carbonarius*. More specimens, and especially field work directed toward solving this problem, are needed. For the present, keeping the names distinct is less confusing than would be uninformed lumping.

Laphria aimatis new species.

Mystax chiefly black in female; mixed with gray in male; face gray pollinose, more so in male; general vestiture, including beard, pile of thorax and legs mixed gray and black; thoracic and scutellar bristles black. Pleuræ and thorax in general with a faint gray bloom, somewhat intensified to form a divided median stripe. First three segments of abdomen and sides of others black with chiefly white pile which is long at sides of anterior segments. Discal portions of segments 4–7 dull to bright ferruginous with golden hair; sometimes a trace of this coloring on third segment, and scattered golden hairs on black integument. Wings smoky, paler toward base. Forceps stout, curved as viewed from above; inner apical process, striate, somewhat twisted longitudinally, narrowed at apex and not attaining apex of forceps. (Figs 12, 12b). Length 14–24 mm.

Type, a male from California, Baron, (U. S. N. M.); allotype, same data, (Kans. Univ).

Other specimens examined: Colorado, (U. S. N. M.); El Paso Co., Colo., June 7, 1914, Champlain, (U. S. N. M.); California, Edwards, (M. C. Z.); Sierra Nevada, California, (Kans. Univ); Placerville, Calif., March 12, 1913, (U. S. N. M.).

This species agrees better than any other I have seen with the description of *L. œatus* Walker. (List 2, 1849, pp. 381-2 [St. Martin's Falls, Albany River, Hudson's Bay, Nova Scotia]), but the size is somewhat different (*œatus* is 6 to 8 lines) and the geographical distribution does not encourage identification of the two. If Walker's remark "thinly clothed with hairs" applies to the abdomen of *L. œatus* there is no question that *aimatis* is a distinct species. Until the type of *œatus* is studied or at least until topotypic material is seen, it is better to use a new name. In various collections no fewer than 5 different species have been found wrongly labelled as *œatus*. The most important point that has been overlooked in making these determinations is Walker's statement that the abdomen is "ferruginous * * * * clothed with ferruginous hairs."

Laphria sadales Walker.

Laphria sadales, Walker, Francis. List of the specimens of Dipterous Insects in the collection of the British Museum, 2, 1849, pp. 378–9. (New York.)

Laphria pubescens, Williston, S. W. Trans. Am. Ent. Soc. 11, 1884, p. 32. (Washington Territory and Mt. Hood, Oregon.)

Mystax black; decumbent pile at sides of face, beard and coxal hair, silvery white; areas bearing this pile and an oblique ellipse on each antero-lateral face of thorax, gray pollinose. Fine short pile of thorax and abdomen golden; in some specimens rather grayish on first and second segments especially at sides. Femora and tibiæ yellowish or reddish with whitish to golden hairs and black bristles; remainder of legs black. Wings fumose, paler toward base. Hypopygium reddish to black; forceps curved as seen from above, inner apical process, short, pale, striate, slightly surpassing end of forceps. (Fig. 13). Length 9–16 mm.

Specimens examined: White Mountains, N. H. Morrison, (U. S. N. M.); Mt. Washington, N. H., Geo. Dimmock, (U. S. N. M.); Franconia, N. H., Geo. Dimmock, (U. S. N. M.); Rutland, Vt., Aug., 1916, Chittenden, (Hine); Axton, N. Y., June, 1901, A. D. MacGillivray, (Hine); Nicolum River, Hope, B. C., July 13, 1906, (Hine); Hope Mts., B. C., July 27, 1906, R. V. Harvey, (Hine); Kaslo, B. C., May 30, June 1, H. G. Dyar, (U. S. N. M.); Washington Territory, (Kans. Univ.); Olympia, Wash., (U. S. N. M.); Pullman, Wash., July 6, H. E. Burke, (U. S. N. M.); Mt. Hood, Ore., H. K. Morrisson, (U. S. N. M.); Fieldbrook, Calif., May 29, 1903, H. S. Barber, (U. S. N. M.); Humboldt Co., Calif., June 14, H. S. Barber, (U. S. N. M.).

Laphria felis Osten Sacken.

Lampria felis Osten Sacken. Bul. U. S. Geol. and Geogr. Survey Terr. 3, 1877, p. 286. (Webber Lake, Sierra Nevada, Calif.)
Laphria felis Williston. Trans. Am. Ent. Soc. 12, 1885, p. 54.
Laphria xanthippe Williston. Trans. Am. Ent. Soc. 11, 1884, pp. 31–32. (Mt. Hood, Ore.)

Williston (loc. prim. cit.) first included *Lampria felis* Osten Sacken under *Laphria*, noting that the femora do not show the tubercles characteristic of that genus. Mr. Nathan Banks has kindly corroborated this information by examination of the type. *L. xanthippe* Williston differs from *L. felis* only in variable color characters.

The principal variations in color are specified in the subjoined key to the varieties. A general characterization is:

Mystax black (yellow in var. *crocea*), beard and coxal hair white in male, grayish to black in female, decumbent pile at sides of face silvery. Inner margin of orbits and oblique fascia on front of thorax silvery or gray pollinose. Short sparse hair on disk of thorax and scutellum appearing light golden in some lights, blackish in others. First two segments of abdomen and most of third, black, with white pile, longer on sides near base; remainder of abdomen except sides of some segments yellow to red-brown. This color is pale in males and the pile is golden; duller in females with the pile black. The bristles of thorax and vestiture of legs, except the usual velvety golden pile on inner face of front ones, are black. Wings smoky even to base; interior of some cells clearer. Hypopygium yellowish or reddish with black hairs; forceps curved as seen from above; inner apical process a little longer and more pointed than in *L. sadales* and recurrent further along inner margin of forceps; slightly separated from forceps as seen from side and more or less decurved at tip. (Figs 14, 15). Length 13–18 mm.

Key to Color Varieties.

a. Mystax black.
  b. Legs entirely black....................................var. *atripes* n. var.
  bb. Legs not entirely black.
    c. Legs not entirely reddish.
      d. Hind femora reddish below.....................var. *xanthippe* Williston.
      dd. Hind femora entirely reddish; others reddish below..var. *varipes* n. var.
    cc. Legs entirely reddish...........................var. *felis* Osten Sacken.
aa. Mystax yellow to golden; legs entirely yellowish to reddish..var. *crocea* n. var.

Laphria felis var. **atripes** new variety.

Type a female from Jenny Creek, Tolland, Colo., July 27, 1917, E. C. Jackson, (U. S. N. M.).

Laphria felis var. **xanthippe** Williston.

Mt. Hood, Ore., H. K. Morrison, (U. S. N. M.).
Hope Mts., B. C., July 24, 1906, R. V. Harvey, (Hine).

Laphria felis var. **varipes** new variety.

Colorado, (U. S. N. M.); Beulah, N. Mex., July 22, Cockerell. A male, the type, (U. S. N. M.).

Laphria felis var. **felis** Osten Sacken.

Kaslo, B. C., June 8, R. P. Currie, (U. S. N. M.); Yellowstone Park, July 25, 1907, W. Robinson, (Hine); Currant Creek, 8,000 feet, Uinta National Forest, Utah, Aug. 13, 1917, J. Silver, (Biol. Survey).

Laphria felis var. **crocea** new variety.

Type a male from Pullman, Washington, July 6, H. E. Burke, (U. S. N. M.).

Other specimens examined: Mt. Hood, Ore., H. K. Morrison, (U. S. N. M.); Hope Mts., B. C., July 18 and 27, 1900, R. V. Harvey, (Hine).

I am tempted to call this form a distinct species, and would, except for the fact that two males from Mt. Hood, Ore., one var. *xanthippe* and one var. *crocea* are so nearly alike in almost all respects except the color of mystax and beard, that it makes me doubt whether the slight differences in genitalia (Fig. 15) are significant.

Laphria scorpio new species.

Mystax black, decumbent pile of face golden in male, whitish to greenish yellow in female. Beard and coxal hair grayish to silvery. Face, coxæ, oblique anterior fascia of thorax and pleuræ, more or less gray to white pollinose. Rather sparse pile of thoracic disk and scutellum mostly golden; more decumbent and conspicuous behind. Thoracic bristles black except tuft in front of halteres which is yellowish. Pile of abdomen golden, being more recumbent on posterior parts of segments and of abdomen as a whole, it there appears more dense. Hair of legs gray and black; wings pale fumose. Hypopygium black; forceps stout, curved; inner apical process, twisted longitudinally so that its median part lies in a vertical plane, surpassing forceps a little and deflexed apically so that it almost touches apex of forceps. A pair of the hooks from interior of hypopygium often are in such a position as to obscure the relative positions of process and apex of forceps. There is also some variation in the shape and deflexion of process (illustrated in Figure 16), but for the present these are not given taxonomic recognition. Length, 14–17 mm.

The females, difficult to distinguish from those of the following two species, may best be recognized by the hair of thorax being almost uniform in color and not forming a distinct median narrow golden triangle.

Type male and allotype female, White Mts., Morrison, (U. S. N. M.). Several paratypes with same date and one female from Camel's Hump, Vt., P. S. Sprague, (U. S. N. M.).

A male from Chateaugay, N. Y., and a female from New Hampshire, (M. C. Z.).

Laphria index new species.

Mystax black; pollen and decumbent pile of face silvery; occiput, coxæ, pleuræ, fascia on front of thorax, gray to white pollinose, hair where present concolorous. Thorax with a median triangle of pale to reddish golden hair, about as wide of scutellum behind, rapidly narrowing and evanescent anteriorly; remaining pile on disk of thorax consisting of longer whitish, sometimes golden, and shorter black hairs, bristles black. Hair on scutellum tends to be paler and the marginal bristles are white. Pile of abdomen, except for whitish hairs on sides of first three segments, pale to reddish golden; rather dense in well preserved specimens, but apparently rather easily lost. Hair of legs gray and black. Wings fumose paler toward base. Hypopygium black, black bristled; apical process somewhat reddish, beveled on outer side, but not twisted, decurved forming with apex of forceps a figure like an opposed thumb and index finger. (Fig. 17). Length 13–18 mm.

So far I have not found a way of certainly distinguishing the females of this species from the next; they appear to be the more robust specimens with the golden thoracic triangle more conspicuous.

Type, a male, Harrisburg, Pa., June 15, 1913, Champlain, (U. S. N. M.).

Other specimens examined: Canada, (U. S. N. M.); White Mts., N. H., (U. S. N. M.); New York, (M. C. Z.); Fort Lee, N. J., May 30, R. C. Osburn, (Hine); Pennsylvania, (K. U.); Harrisburg, Pa., June 28, 1912, Champlain, (Walton), June 15, 1917, W. S. Fisher, (Fisher); June 4, 1915, July 20, 1916, June 12, 1914, June 5, 1914, March 20, 1915, pupa collected, W. S. Fisher, (U. S. N. M.); Lingletown, Pa., May 21, 1915, May 17, 1915, pupa collected, W. S. Fisher, (U. S. N. M.); Stoverdale, Pa., June 6, 1916, W. S. Fisher, (U. S. N. M.); Dead Run, Va., May 27, 1917, W. L. McAtee, (Biol. Survey).

Females from North Carolina, Ohio, Illinois and Wyoming may be this or a related species. The Illinois specimen is labelled *ferruginea* Le Baron ms. Mr. Banks informs me that a specimen in the Museum of Comparative Zoology bears the manuscript name *walkeri* Loew.

Laphria ithypyga new species.

Scarcely differs from last in general appearance, but male genitalia are very distinct. Hypopygium black, black bristled, straighter than usual in the genus; apical process not twisted, broad, stout, forming the principal part of apex of forceps; hollowed out within and forming with lower apical angle of forceps a considerable emargination which is broadest distally. (Fig. 18). Length 12–17 mm.

Type, male, Harrisburg, Pa., June 18, W. R. Walton, (U. S. N. M.).

Other specimens (males) examined: Lingletown, Pa., August 4, 1912, Champlain, (Walton); Harrisburg, Pa., July 20, 1916, W. S. Fisher, (Fisher); Philadelphia, Pa., (Hine); Beltsville, Md., June 4, 1916, W. R. Walton, (Walton).

Laphria sicula new species.

Laphria canis, in large part, of previous authors, not of Williston according to the male type.

Mystax black; face, occiput, coxæ, pleuræ and usual oblique fascia on front of thorax gray to white pollinose, with hair where present mostly concolorous. Thoracic bristles and tuft in front of halteres black. Sparse pile of thoracic dorsum white, of abdomen black and white, the latter more prominent on sides of posterior parts of segments. Legs with black and white hair. Wings dark fumose, slightly paler toward base. Hypopygium black with black bristles and a few pale hairs on end of anal valve; forceps from above stout, curved abruptly, tapering to rather acute apex; from side, appearing shallowly emarginate at apex, claspers borne by forceps unusually stout and extraordinarily large at base where inserted in forceps. (Fig. 19). Length 9–14 mm.

Type male and allotype female, taken in copula, Plummers Island, Md., July 21, 1907, A. K. Fisher, (U. S. N. M.).

Records for other females of this species are not given for the reason that with present knowledge they are not separable from females of *L. canis* and of *L. winnemana*.

The males examined represent the following localities: Heckton Mills, Pa., June 15, 1909, W. R. Walton, (Walton); Lingletown, Pa., Aug. 5, 1915, W. S. Fisher, (U. S. N. M.); Great Falls, Va., June 29, 1915, August 17, 1916, August 28, 1917, C. T. Greene, (U. S. N. M.); Scott's Run, Va., July 25, 1915, W. L. McAtee, (Biol. Survey); Langley, Va., July 16, 1911, W. D. Appel, (U. S. N. M.); Dead Run, Va., June 9, 19, July 25, 1915, R. C. Shannon, (U. S. N. M.); Falls Church, Va., July 3, 1916, J. N. Knull, (U. S. N. M.); Plummers Id., Md., June 18, 1914, R. C. Shannon, July 14, 1907, A. K. Fisher, (U. S. N. M.); June 30, 1907, July 14, 1907, A. K. Fisher, (Biol. Survey); Lakeland to Riverdale, Md., July 14, 1916, W. L. McAtee, (Biol. Survey); Ira, Summit Co., Ohio, July 24, 1910, (Hine); Urbana, Ill., July 15, 1915, (Ill. State Lab. Nat. Hist.); Monticello, Ill., June 30, 1914, (Ill. State Lab. Nat. Hist.).

Laphria franciscana Bigot.

Laphria franciscana Bigot, J. M. F. Dipteres nouveaux ou peu connus. 10 (1). Annales de la Societe Entomologique de France, 5th ser., 8, 1878. p. 225. (California.)

There is little in general appearance to distinguish this species from *L. sicula.* In both of these species the females have less pale hair among bristles of mystax (sometimes none), and less white hair on sides of abdominal segments. In both sexes, *L. franciscana* has notably less of the latter pile than has *sicula.* I am unable to perceive any differential coloring of thoracic pile, all of it appearing pale when held in the proper light.

Both species have a shining, opalescent, bluish, black surface which is characteristic. Color of hypopygium and its hairs as in *L. sicula;* forceps from above stout, curved, constricted beyond middle, then expanded into a hollowed out spoon shaped apex; from side only slightly emarginate apically, claspers not so stout and without large basal insertion as in *sicula* (Fig. 20). Length 12–16 mm.

Specimens examined: Grouse Mt., B. C., June 29, 1905, (Hine); Western Washington Territory, H. K. Morrison, (U. S. N. M.); Siskiyou Co., Calif., (U. S. N. M.); Santa Cruz Mts., Calif., (U. S. N. M.).

A general and somewhat damaged specimen from Cayuga Lake, N. Y., (M. C. Z.), has genitalia more like *franciscana* than *sicula*, but agrees better with the latter in the amount of white pile on abdomen. On account of its condition it is not more definitely placed.

It should not be overlooked that the present identification of *L. franciscana* is perfunctory. Without examination of the type no identification of a species of *Laphria* is beyond question.

Laphria canis Williston.

Laphria canis, Williston, S. W. Trans. Am. Ent. Soc. 11, 1884, p. 31. (Connecticut.)

Laphria dispar Banks. N. Four new species of Asilidæ. Can. Ent. 43, No. 4, April, 1911, p. 130. (Ithaca, N. Y., Hecton Mills, Pa.).

Laphria disparella nom. nov. Banks, N. Notes on Diptera Proc. Ent. Soc. Wash. 15, No. 1, April, 1913, p. 52. For *L. dispar* Banks not Coquillett.

Examination of the male type of *L. canis* Williston regrettably necessitates the above synonymy. I have a cotype male of *L. disparella* Banks and the correctness of my figures of the genitalia has been verified from the type by Mr. Banks.

The type of *L. canis* is of a variety which I had intended to describe as a new variety of *L. disparella,* but which now of course becomes the typical form.

Laphria canis variety **canis** Williston.

Mystax black; decumbent pile at sides of face silvery; coxal hair, beard, in fact all pubescence of lower half of occiput grayish, of upper half black. Pollinose areas as in related forms. Body thinly clothed with pale pile, which on thorax appears slightly golden in some lights and black in others. Thoracic bristles, except tuft in front of halteres, black, the latter, pale. Scutellar bristles pale to black. Pale hair of abdomen is longest and whitest on sides of segments, especially toward base of abdomen; some of the short pubescence appears black in some lights, especially on last segment, where some of it also is golden. Hair of legs black and white. Wings slightly fumose. Hypopygium black, black haired except for a tuft of pale hairs on apex of anal valve; forceps from above stout, abruptly tapering to a rounded and slightly upturned apex; a view within shows that forceps is strongly hollowed out and that a thin plate forms the inner apical portion between the thickened apical ridge and body of forceps; from side hypopygium appears unusually inflated, almost globular, forceps simple in exterior modeling, its apical projection nearly straight, the margin slightly reflexed below. Length 12 mm. (Description from type).

Other specimens from which figures (Fig. 21) of genitalia were taken, show variation in length from 9 to 14 mm.

Specimens examined: Connecticut, type, (Kans. Univ.); New Haven, Conn., June 4, 10, 1911, Champlain, (Walton); Perdix, Pa., May 27, 1911, W. S. Fisher, (Walton); Enola, Pa., June 13, 1909, (Walton); Carlisle Junction, Pa., June 22, 1909, W. R. Walton, (Walton); Plummers Id., Md., June 4, 1916, H. L. Viereck, (Biol. Survey); Virginia, near Plummers Id., Md., June 7, 1908, W. L. McAtee, (Biol. Survey); Dead Run, Va., July 18, 1916, R. C. Shannon, (U. S. N. M.); Glencarlyn to Mouth, Four-mile Run, Va., June 11, 1916, W. L.

McAtee, (Biol. Survey); Falls Church, Va., July 3, 1916, J. N. Knull, (U. S. N. M.); Vinton, Ohio, June 5–12, 1900, (Hine); Ira, Summit Co., Ohio, (Hine).

Laphria canis var. **disparella** Banks.

Bibliographic references previously.

Variety *disparella* is distinguished from the typical variety by the golden color of hair on the abdomen and sometimes of the pile on face.

Mystax black, decumbent pile of face white to golden. Pollinose areas as in typical form. Beard and coxal hair gray to silvery. Short, sparse hair of thoracic disk, tuft in front of halteres and scutellar pile and bristles pale, tinged with golden. The scutellar bristles and halteral tuft vary to black. Hair of abdomen rather sparse, golden, most noticeable on hind margins and posterior abdominal segments.

Specimens examined: Heckton Mills, Pa., June 15, 1909, W. R. Walton, cotype, (Walton); Inglenook, Pa., June 9, 1911, W. S. Fisher, June 27, 1912, Champlain, (Walton); Inglenook, Pa., June 14, 22, 1917, W. S. Fisher, (Fisher); Lingletown, Pa., June 8, 1912, Champlain, (Walton); Harrisburg, Pa., June 17, 1912, Champlain, June 18, July 7, W. R. Walton, (Walton); Ithaca, N. Y., June 9, 1906, (Hine).

Laphria winnemana new species.

Mystax black, decumbent pile of face silvery. Beard and coxal hair grayish white; usual areas pollinose. Thoracic bristles and tuft in front of halteres black. Short sparse hair of thoracic dorsum pale golden when viewed from in front, appearing black in some lights; longer hair of scutellum pale golden, bristles pale to black. Abdomen with sparse pale hair which is especially long at sides and mostly white on first three segments, and mostly golden (may appear black in some lights) on remaining segments, being especially prominent on seventh. Long hair beneath abdomen very pale golden; hair of legs gray and black. Wings dark fumose paler toward base. Hypopygium black with black and white hairs; forceps from above abruptly narrowed into a slender process which is enlarged into a dilated trapeziform apex. The lamella along inner apical margin is directed downward and opaque, not more horizontal and translucent as in *L. canis*. From side forceps appears much like that of *L. canis*, the lamella just mentioned being much more conspicuous however. (Fig. 22). Length, 11–14 mm.

Type a male from Plummers Island, Md., July 11, 1909, W. L. McAtee, (U. S. N. M.).

Other specimens examined: Plummers Id., Md., June 27, 1915, R. C. Shannon, (U. S. N. M.); Scotts Run, Va., August 12, 1917, W. L. McAtee, (Biol. Survey); Great Falls, Va., June 28, 1917, C. T. Greene, (U. S. N. M.); Dead Run, Va., July 11, 1915, July 18, 1916, July 28, 1915, R. C. Shannon, (U. S. N. M.); Maryland, near Plummers Id., June 30, 1914, R. C. Shannon, (U. S. N. M.); Marsh Run, Pa., July 16, 1909, (Walton); A teneral specimen labelled only Can. (U. S. N. M.) appears to be this species.

Laphria saffrana Fabricius.

Laphria saffrana Fabricius, J. C. Systema Antliatorum secundum ordines, genera, species adiectis synonymis, locis, observationibus, descriptionibus, 1805, p. 160. (California).

Mystax, facial and occipital pile, hair of coxæ and legs, two tufts on each side of thorax, two on disk, margin of disk of thorax (broadly interrupted anteriorly, narrowly so posteriorly) and dense pile of abdomen, yellow to bright golden or reddish yellow. The hairs of palpi are dark reddish and a little hair beneath mystax is blackish. Body surface piceous where exposed, contrasting strongly with the yellow pile; integument of legs yellow. The disk of thorax, except for yellowish areas mentioned, and the scutellum are covered with short black pile. Wings fumose. Hypopygium reddish with pale hairs; forceps, stout, straight, apex on inner side as seen from above, rounded angulate, inner edge near base with an inwardly and downwardly projecting broad lobe; seen from side forceps is oblique at apex, and shallowly emarginate, both on apex and lower side. (Fig. 23). Length 17–25 mm.

Specimens examined: St. Elmo, Va., F. C. Pratt, (U. S. N. M.); Tryon, N. C., W. F. Fiske, (U. S. N. M.); Southern Pines, N. C., April 21, 1908, May 2, 12, 14, 15, 1908, (Hine); Billys Id., Okefenokee Swamp, Ga., June, 1912, (Hine); Southern Georgia, Morrison, (U. S. N. M.); Florida, (Hine, Ill. State Lab. Nat. Hist.); Sand Point, Fla., May 3, (U. S. N. M.); Archer, Fla., March, 1882, (U. S. N. M.).

Kertesz puts* *Laphria saffrana* in the genus *Dasyllis* and the genital forceps, admittedly are somewhat similar to those of species of that genus. (See Figs. 24, 25). *L. saffrana* does not have the *Dasyllis* habitus however, which is chiefly due to abundant, long, spreading pile, in large areas of strongly contrasting colors. The short crisp pile of *saffrana* seems to ally it more with the species of *Laphria*.

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* Kertesz, C. Catalogus Dipterorum, 4, 1909; p. 174.

EXPLANATION OF PLATES.

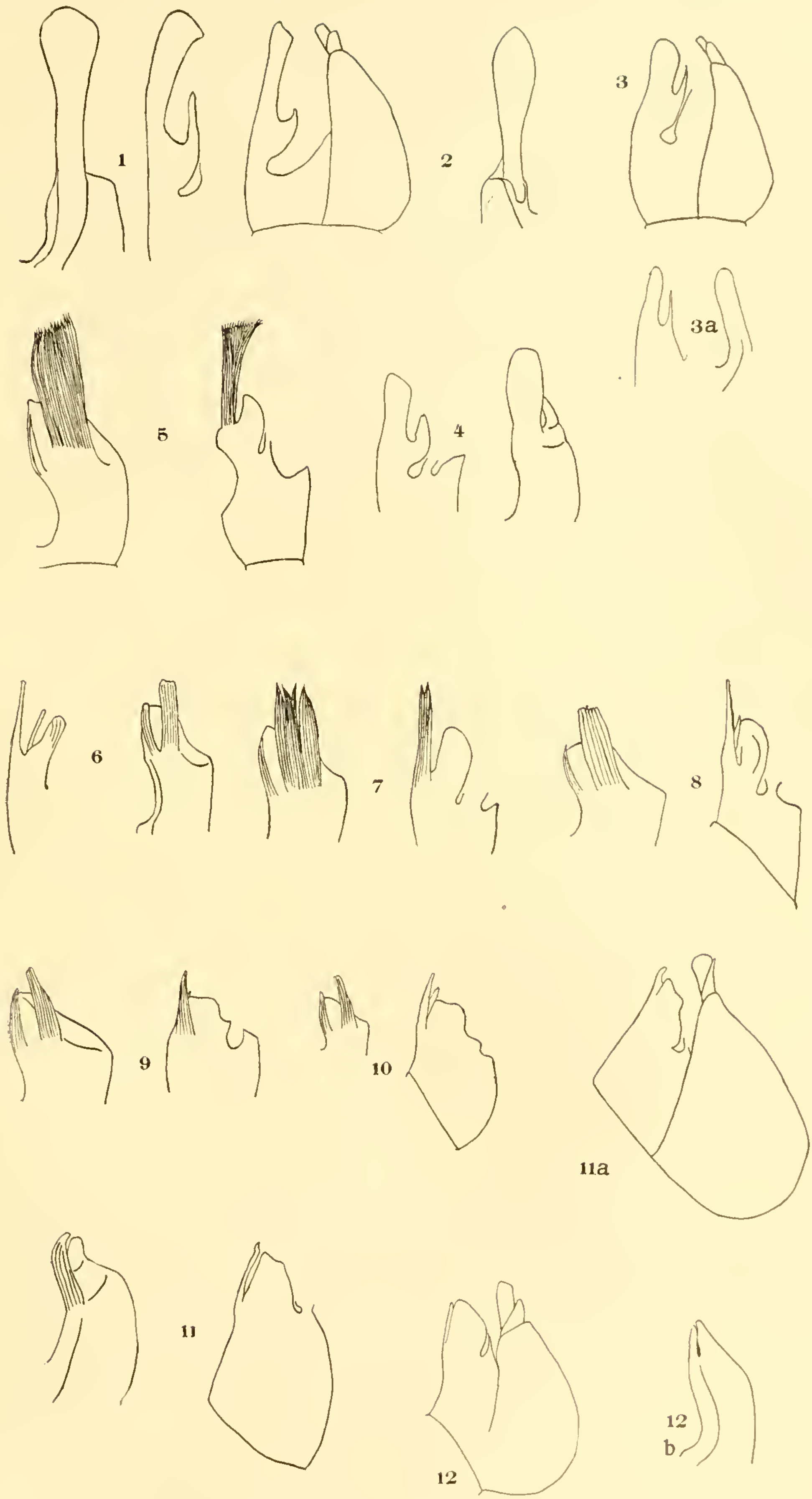
Plate X.

Fig. 1. *Laphria vultur:* forceps from above and from side.
Fig. 2. *Laphria sericea:* hypopygium from side; forceps from above.
Fig. 3. *Laphria aktis:* hypopygium from side.
Fig. 3a. *Laphria aktis:* forceps from side and from above.
Fig. 4. *Laphria janus:* forceps from side and from above.
Fig. 5. *Laphria ferox:* forceps from above and from side.
Fig. 6. *Laphria gilva:* forceps from side and from above.
Fig. 7. *Laphria vivax:* forceps from above and from side.
Fig. 8. *Laphria vivax anthemom:* forceps from above and from side.
Fig. 9. *Laphria ventralis:* forceps from above and from side.
Fig. 10. *Laphria coquillettii:* forceps from above and from side.
Fig. 11. *Laphria trux:* forceps from above and from side.
Fig. 11a. *Laphria trux:* hypopygium from side.
Fig. 12. *Laphria aimatis:* hypopygium from side.
Fig. 12b. *Laphria aimatis:* forceps from above.

Plate XI.

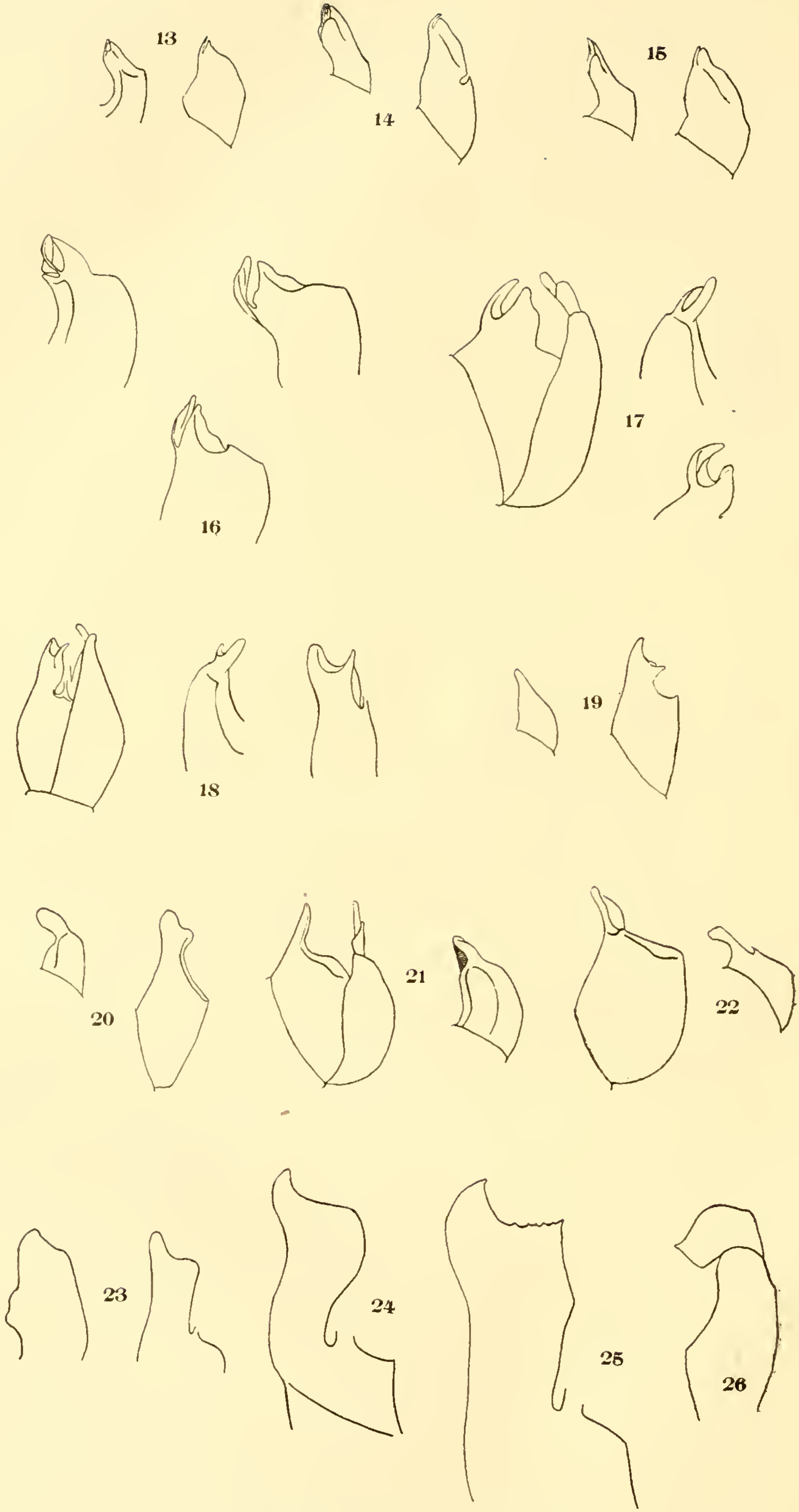
Fig. 13. *Laphria sadales:* forceps from above and from side.
Fig. 14. *Laphria felis:* forceps from above and from side.
Fig. 15. *Laphria felis var crocea:* forceps from above and from side.
Fig. 16. *Laphria scorpio:* forceps from above, from side (lower figure), and showing greatest emargination (upper right).
Fig. 17. *Laphria index:* hypopygium from side; forceps from above, and showing greatest emargination (lower right).
Fig. 18. *Laphria ithypyga:* hypopygium from side; forceps from above and showing greatest emargination.
Fig. 19. *Laphria sicula:* forceps from above and from side.
Fig. 20. *Laphria franciscana:* forceps from above and from side.
Fig. 21. *Laphria canis:* hypopygium from side; forceps from above.
Fig. 22. *Laphria winnemana:* hypopygium from side; forceps from above.
Fig. 23. *Laphria saffrana:* forceps from above and from side.
Fig. 24. *Dasyllis fernaldi:* forceps from side.
Fig. 25. *Dasyllis grossa:* forceps from side.
Fig. 26. *Nusa* n. sp. near *rubida*: forceps from side.

All Figures about 3.3 times natural size.



Male Genitalia of Laphria

W. L. McAtee



Male Genitalia of Laphria

W. L. McAtee

Scientific Results of the Katmai Expeditions of the National Geographic Society.

IV. THE CHARACTER OF THE ERUPTION AS INDICATED BY ITS EFFECTS ON NEARBY VEGETATION.*

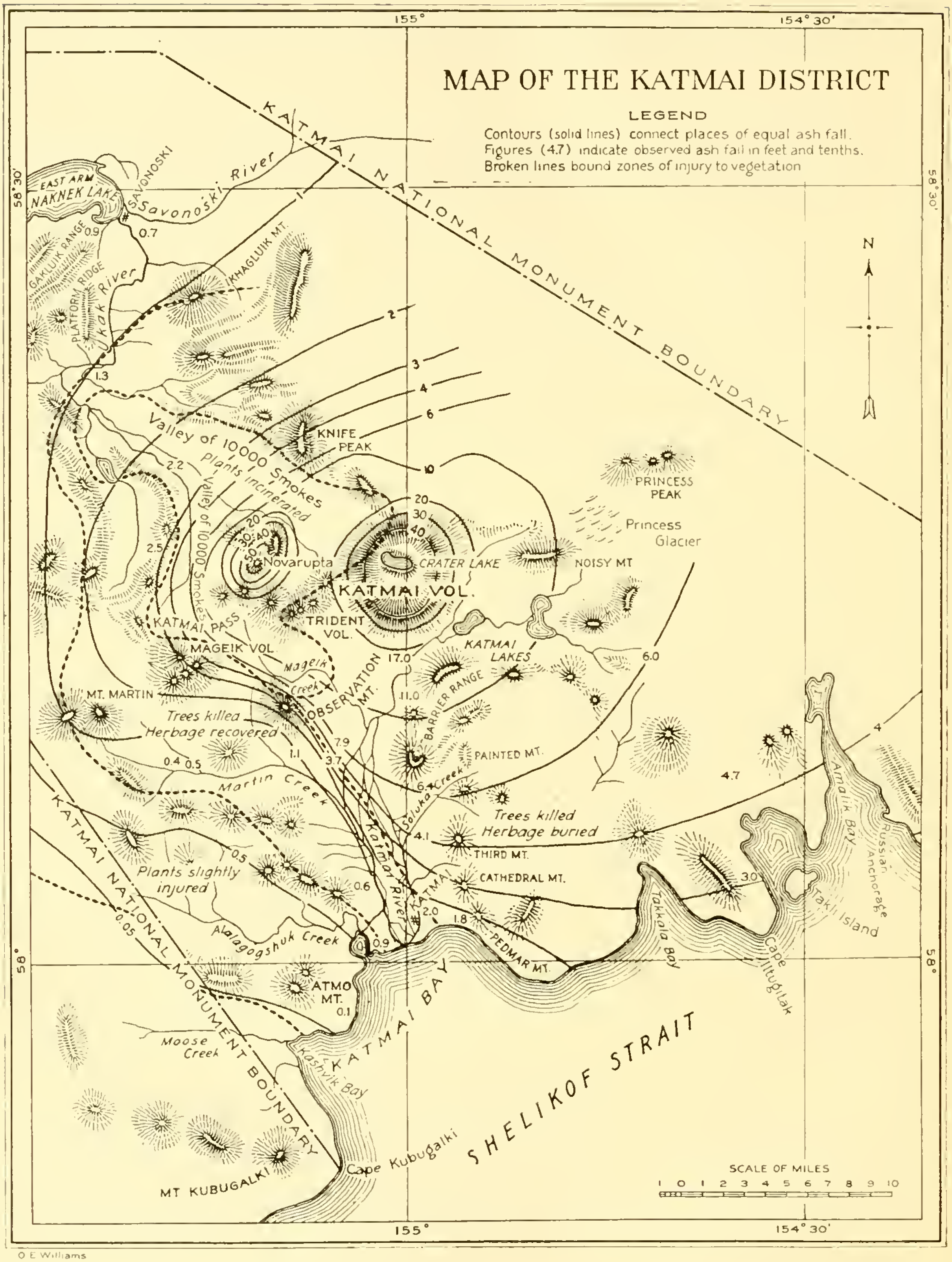
Robert F. Griggs.

Since the country affected by the eruption of Katmai, in June, 1912, is an uninhabited wilderness, there were no eye-witnesses of the eruption located near enough to give any account of what happened within 25 miles of the volcano. There are, therefore, many features of this, one of the greatest and most interesting of all eruptions, which can never be known except as they are deduced from evidence left behind. Of such evidence that afforded by the effect of the eruption on vegetation is by far the most instructive.

While the largest value of an examination into the nature of the fate that overtook the plants of the devastated area lies, perhaps, in its use in interpreting the events of the eruption itself, it has another interest of almost equal importance. It is a necessary prerequisite to the studies of the revegetation of the ash-covered country, which were the primary objects of the Katmai expeditions, because of the manifold bearings of such studies on many problems of the soil relations of plants, both of a theoretical and of a practical nature. We shall combine these two interests in this paper, giving not only such data as contribute to an understanding of the eruption, but also discussing the restorative reactions of the surviving plants so as to form a basis for the papers on revegetation which are to follow.

THE ZONES OF DAMAGE.

As marked by the extent of injury to vegetation, the country affected by the eruption may be divided into several zones of damage. In the outermost zone the plants suffered from acid rains, but the ashfall was so light as to do no damage of conse-


MAP OF THE KATMAI DISTRICT
LEGEND
Contours (solid lines) connect places of equal ash fall.
Figures (4.7) indicate observed ash fall in feet and tenths.
Broken lines bound zones of injury to vegetation
155°
154° 30'
58° 30'
58°
KATMAI NATIONAL MONUMENT BOUNDARY
NAKNEK LAKE
EAST ARM
SAVONOSKI
Savonoski River
KHAGLUIK MT.
GAKLUIK RANGE
PLATFORM RIDGE
Ikak River
KNIFE PEAK
Valley of 10000 Smokes
Plants incinerated
Novarupta
CRATER LAKE
KATMAI VOL.
NOISY MT
PRINCESS PEAK
Princess Glacier
KATMAI PASS
TRIDENT VOL.
MAGEIK VOL.
Mageik Creek
OBSERVATION MT.
KATMAI LAKES
BARRIER RANGE
MT. MARTIN
Trees killed
Herbage recovered
PAINTED MT.
Martin Creek
Soluka Creek
Trees killed
Herbage buried
THIRD MT.
CATHEDRAL MT.
Plants slightly injured
Katmai River
KATMAI
Alalagogshuk Creek
PEDMAR MT.
Takkola Bay
Cape Ilturgitak
Amalik Bay
Russian Anchorage
Takli Island
ATMO MT.
KATMAI BAY
Moose Creek
Kashvik Bay
SHELIKOF STRAIT
Cape Kubugalki
MT KUBUGALKI
SCALE OF MILES
1 0 1 2 3 4 5 6 7 8 9 10
N
O E Williams

quence. In the second zone, covering parts of Kodiak and Afognak Islands, the ashfall was so heavy as to do great damage to the smaller plants, but the trees and bushes that protruded were comparatively unaffected. The third zone includes those areas of slighter injury on the mainland. In the fourth zone the trees and bushes were killed but the grass has come back without permanent injury. In the fifth zone not only were the trees killed, but the ashfall was so heavy that the herbage as well was destroyed except where the ground was later cleared. In the sixth zone every vestige of life was consumed by fire, leaving the country absolutely sterile. The areas covered by these zones are shown by the map given herewith. (See page 174). It will be observed that they are not concentric belts lying one inside the other, but are to a considerable extent independent, occupying different sectors of the area around the volcano. Because of the geographical peculiarities of the country, moreover, they intergrade very little, at least in those areas so far explored, but are rather sharply separated from each other by definite geographical boundaries.

OUTLYING AREAS INJURED BY ACID RAINS.

On account of the unsettled condition of the country affected, and particularly because the interests of the scanty population are not agricultural, the damage to plants at great distances from the volcano was a matter of very much less concern than it would have been in a populous agricultural country. Observations of damage to plants were therefore never recorded at all in many cases, and where published were simply printed as news items in the local papers. The records are, therefore, much scattered and difficult to secure, but it should not be supposed on this account that damage to vegetation in the outermost zone was insignificant in amount.

At La Touche in Prince William Sound, some 300 miles east of the volcano, Mr. F. R. Van Campen, then superintendent of the mines, in a private letter, states that following the eruption the rain was so acidulated by the fumes as to cause stinging burns wherever it touched the flesh. He had his chemist analyze this rain and found that the trouble was caused by sulphuric acid which was present in considerable quantity. Unfortunately the analysis giving the precise concentration of the acid has been lost. This acid rain did serious injury to the leaves of the native perennial vegetation, in some cases causing defoliation. But to the cultivated annuals of the gardens it was so injurious as to cause their complete destruction.

The magnitude of this feature of the eruption can be better envisaged if one imagine the volcano located in New York City, in which case crops would be destroyed as far away as Pittsburgh, Portland, (Maine), and Richmond, (Virginia). It would not be fair to suppose, however, that in such a hypothetical eruption all crops would be destroyed within the area indicated, for the occurrence of such acid rains is sporadic, being dependent both on the drift of the fumes under the wind and on the occurrence of the atmospheric conditions necessary to produce precipitation at the time when the acid laden clouds were passing over the given area.

The effects of the eruption on vegetation in the vicinity of Kodiak, which is typical of the second zone where the ashfall was so heavy as to smother all of the smaller plants, have been discussed in earlier papers and require no amplification here.[1-2-3]

Conditions in the third zone, comprising the outlying fringes beyond the areas of greater destruction on the mainland, may be best described after consideration of the inner zones.

TREES KILLED IN AREAS OF LITTLE ASHFALL.

The fourth zone, where trees and bushes were killed, although the ashfall was so light as not to destroy the herbage, occupies an area of about 666 square miles lying to the south, west, and north of the volcano, beginning with the west side of Katmai Valley and extending around the Valley of Ten Thousand Smokes into the unexplored country to the northeast of the volcano. The position of this zone is determined by the fact that the west wind which blew during the eruption carried the ash cloud off in the direction of Kodiak, so that much of the area relatively close to the volcano was only lightly covered with ash. (See map, page 174.)

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[1] Rigg, Geo. B. The Effects of the Katmai Eruption on Marine Vegetation. Science II. 40: 509–513. 1914.

[2] Griggs, Robert F. The Effect of the Eruption of Katmai on Land Vegetation. Bull. Am. Geogr. Soc. 47: 193–203. Figs. 1–10. 1915.

[3] ———, ——————. Scientific Results of the Katmai Expeditions. I. The Recovery of Vegetation at Kodiak. Ohio Journal of Science. 19: 1–57. Figs. 1–34. 1918. Includes a digest of literature pertinent to the present paper.

The present condition of the vegetation throughout this zone is shown by the pictures on page 178. The trees and bushes are dead or, toward the edge of the zone and in somewhat sheltered places, have here and there a tuft of leaves where a bud survived. Beneath the trees the ground is covered with a rank growth of herbage. The effect of the ashfall here was the same as at Kodiak—namely, to destroy the weaker plants, giving increased opportunity for the strong growing survivals.

Along the west side of Katmai Valley where the ashfall was from 6 to 12 inches, the present herbage is an almost pure stand of grass—*Calamagrostis langsdorfii.* In the Valley of Martin Creek, which was much more lightly covered with ash, there is a considerable variety of other plants beside the grass. In Ukak Valley, where the ashfall exceeded a foot, all these were killed and the present ground cover is horsetail—*Equisetum arvense.* This plant grows here in a luxuriance quite unmatched elsewhere, covering mile on mile of country in pure stand. The plants reach a size about double that usually attained by this species, being fully waist high over large areas. (See page 178.)

The matter of greatest interest to be discussed in connection with this zone is, however, the cause of the death of the trees.

WERE THERE HOT BLASTS IN THE ERUPTION?

It is clear enough on the face of it that the death of these trees cannot be accounted for by the ashfall. Over much of this zone the ashfall is six inches or less, as compared with a foot at Kodiak where the trees were not perceptibly injured.

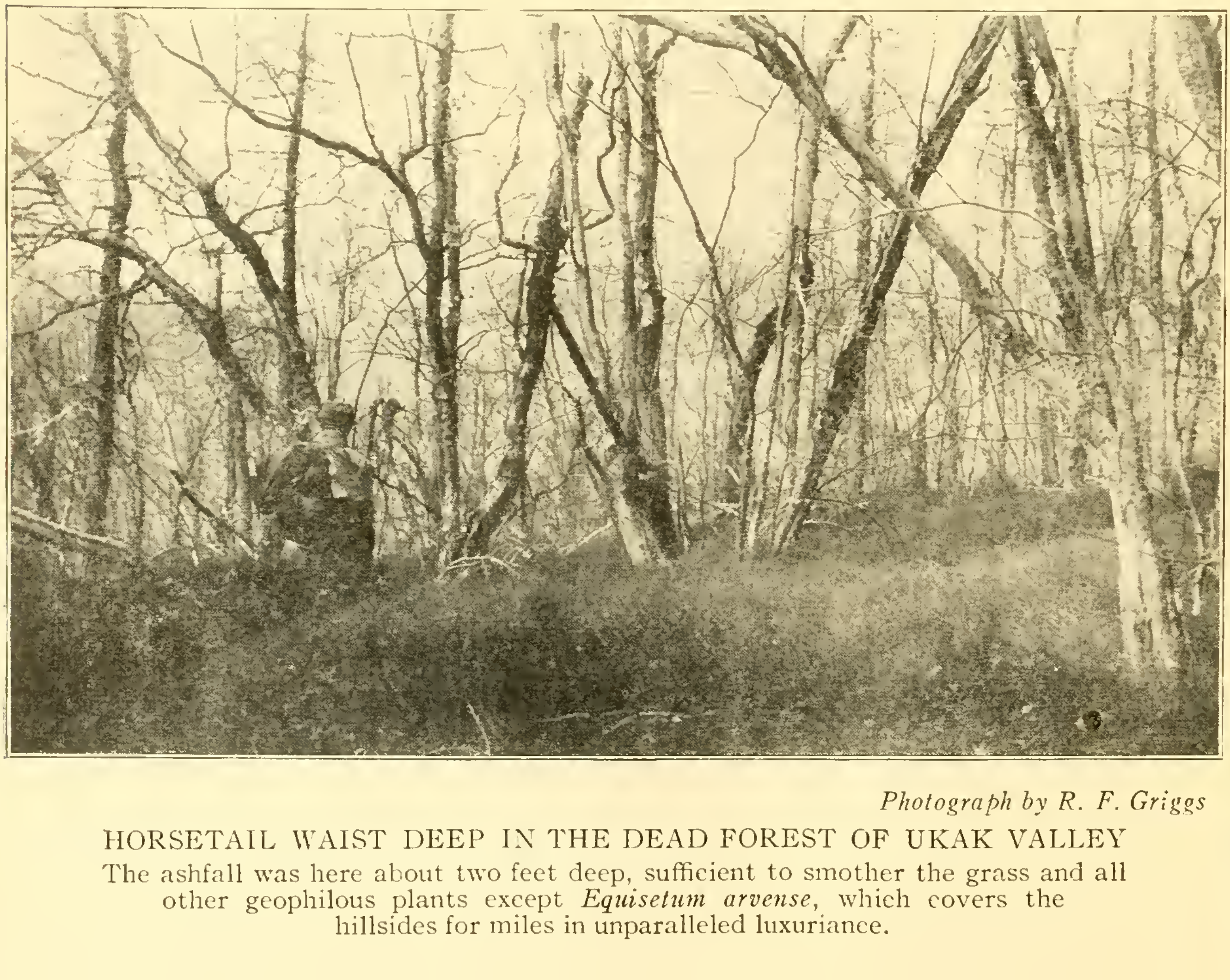
In view of this situation our first inquiry was as to whether Katmai had given forth such hot blasts as characterized many other eruptions, notably those of Pelee and Taal. It may be stated very positively that there is no evidence whatever of any blasts of such tornadic violence as have occurred in many cases. No uprooted trees or other similar evidence of high winds radiating from the crater are to be found. The absence of evidence does not, however, furnish conclusive proof that such blasts did not occur.

The havoc wrought by other agencies was quite sufficient to cover up evidence of tornadoes of hot gas, which in a lesser eruption would have left tremendous devastation in their wake. The ashfall around the crater of Taal, for example, is reported as

Photograph by J. W. Shipley

THE TRAIL THROUGH THE TALL GRASS ALONG THE WEST BANK OF KATMAI RIVER.

Representative of conditions in the fourth zone where the trees were killed but the ashfall was so light that the grass quickly recovered.



Photograph by R. F. Griggs

HORSETAIL WAIST DEEP IN THE DEAD FOREST OF UKAK VALLEY

The ashfall was here about two feet deep, sufficient to smother the grass and all other geophilous plants except *Equisetum arvense*, which covers the hillsides for miles in unparalleled luxuriance.

only 8 to 12 inches,[4] while at Katmai it was 40 feet on the crater rim and 15 feet at a distance of five miles. The flat flood plain of Katmai Valley with its forest of large trees is the place which should have shown the most definite evidence of hot tornadoes. But this was swept by a terrific flood which so tore up the dead forest as to cover up any lesser damage which may have preceded it. Nevertheless it must be noted that the trees are still standing everywhere throughout the Valley, except in areas swept bare by the flood. On the other hand, while violent hot blasts like those that devastated St. Pierre have not been known to retain their power for great distances from the vent, the dead trees under discussion were some of them situated as much as 25 miles away.

But, while there is no evidence of hot blasts of tornadic violence, it is difficult to imagine such widespread destruction as we are dealing with as due to other causes than withering blasts from the volcano, and there is considerable evidence that these were the agents of destruction. Those trees that survived in areas of otherwise complete destruction were invariably so situated as to be sheltered from winds coming from the direction of the crater.

In lower Katmai Valley, which bends so that the east side is sheltered from the volcano while the west side is exposed toward it, all trees were killed on the exposed west side and in the middle of the valley, but under the protecting mountainsides on the east bank isolated buds on many trees survived. The destructiveness of the eruption was even more mitigated in Soluka Valley, which, although only half as far from the crater, was sheltered by the ridge of the Barrier Range. (See map.) This difference is made the more striking by the fact that while the ashfall was six feet in Soluka Creek it was less than two feet at the east side of Katmai Valley, and less than a foot on the west side where the destruction to trees was greatest.

At Russian Anchorage in the left arm of Amalik Bay, 23 miles from the vent, which the writer visited the year after the eruption, the alders on the mountainsides exposed toward the volcano showed no signs of life while on the opposite sheltered slopes they were green with new leaves. This effect could hardly have been produced except by withering winds from the

[4] Worcester, D. C. National Geographic Mag. 23 : 359. 1912.

volcano. That the blasts should have retained their power at such distances is the more remarkable because the intervening country is covered with high mountains, which must have offered great obstruction to their passage. So far as the writer is aware, this is the greatest distance which has been recorded as having been reached by volcanic blasts.

If then, it may be considered that the evidence available is sufficient to establish definitely the presence of destructive blasts at distances up to 25 miles from the volcano, it might be argued *a fortiori* how very violent they must have been close to the crater. But it would not be safe to make such an assertion, especially since there appears to have been at least one important difference between these blasts and most of those previously described.

One of the most striking features of the hot blasts from Pelee, Taal and Lassen is the extreme localization of their effects. In each case only a narrow radial sector of the country around the crater was effected, and the edges of this sector were sharply defined.

The most striking feature of the blast from Katmai, on the other hand, is its general distribution around the whole of the circumference of the crater. Not only did it spread in all directions from the crater, but the distance to which it retained its destructiveness was remarkably uniform, being about 25 miles almost everywhere that it has been observed, with little regard to the character of the intervening country. It was almost as destructive at Amalik Bay, across the mountains, as in the Valleys of Katmai and Ukak Rivers which radiate almost directly from the volcano. The only exception to this condition observed was on the southwest, where the destruction of trees was limited by the divide at the head of Martin Creek, which stands somewhat nearer the volcano.

NATURE OF THE BLAST.

The question of the nature of the devastating blast from the volcano is more difficult to answer from observation so long after the event, but there are a few lines of evidence which may be stated even though it may not be wise to draw positive conclusions. Were poisonous gases given off, or was the destruction due to the high temperature of the blast?

At Kodiak and throughout the area seriously affected there seem to have been sulphur fumes of sufficient concentration to destroy fungous growths, for on our first visit the year following the eruption, all the lichens were found hanging blackened and dead in the trees. Similarly, the natives on the Bering Sea side of the peninsula reported the destruction of the reindeer "moss," with disastrous effects on the herds of caribou that were formerly abundant. Not until four years had passed did living lichens reappear in any quantity at Kodiak. Fungi are, however, very sensitive to sulphur poisoning. The fumes which were sufficient to kill them at Kodiak caused nothing more than temporary discomfort to the people residing in the same district.

Nowhere even close to the volcano itself is there any clear evidence that the seed plants were poisoned by fumes. In many places plants growing in the crevices of the cliffs, although protected from damage from hot air by the cold rocks in which they grew, were so situated that they were fully exposed to the fumes throughout the eruption. Nowhere in such situations did we find the dead remains of poisoned plants. On the contrary, all of the herbaceous plants not covered up by the ash, except those in the fire-swept zone, seem to have gone on flowering and fruiting with undiminished vigor since the eruption. Some of these flowers present most grateful spots of color in a country otherwise totally devastated. (See page 182). Such blooming crevice plants are common throughout the lower and middle portions of Katmai Valley, and numbers of them may also be found in the upper valley close to the volcano.

The survival of three dogs at Katmai Village, noted by Martin, also indicates the absence of poisonous gases in deadly concentration. For, while these animals could probably have survived *hot* blasts of considerable intensity by taking to the native huts, which were half buried and covered with a thick roof of earth and sod, such places would not afford much protection against the penetration of poisonous gases. The evidence, such as it is, seems therefore to favor the hypothesis that the blasts from Katmai did not owe their destructiveness to their chemical composition but to other causes. If this is correct it would fall into line with the best testimony as to the blasts from Pelee and Taal.

In the case of Taal, Worcester[5] believes that the principal reason for the destructiveness was the heavy charge of small

[5] National Geographic Mag. 23 : 350. 1912.

Photograph by R. F. Griggs

A CLUMP OF HAREBELLS IN A CREVICE IN KATMAI VALLEY.

Such crevice plants on exposed cliffs close up to the volcano indicate the absence of any great concentration of poisonous gases in the fumes.

particles of ejecta carried by the blasts, which gave them the effect of terrific sand blasts. This he inferred from the manner in which the bark and trunks of trees were shredded where exposed, and from the fact that even very thin fabrics sufficed to protect the flesh of victims which otherwise suffered severely.

There is, however, little evidence that a sand blast accompanied the eruption of Katmai. Near the volcano and in Soluka Creek, at a distance of about ten miles, the limbs of the trees and bushes were damaged by the *hail* of falling ejecta which must have been of considerable violence in areas where so much ash and pumice fell. But no evidence of shredding by sand blasts, such as Worcester figures, was seen.

The only place on the mainland where investigations were made to ascertain the manner of death of the vegetation within the first year after the eruption was at Russian Anchorage. (Griggs[2]). Here the *buds* of the alders had all been killed, but the bark was not only intact but alive and in condition to have made a complete and rapid recovery if there had been living buds to furnish an outlet for the vitality of the plants. (See page 184.) The present appearance of the trees in Katmai Valley indicates that the eruption probably left them in the same condition. (See page 185.) It is difficult to see how such damage could be accomplished by a sand blast. It would seem much more likely to have resulted from hot winds.

As would be expected, the zone of complete destruction by the blast is surrounded by an area of minor injury. This is the third of our series of zones which we passed over above without discussion. It has been observed, especially in the area between the mouth of Katmai River and Kashvik Bay. Because of the position of the mountain wall of Katmai Valley, the area of devastation does not intergrade with this district of slight injury but is sharply separated from it.

Since this district lies out of the area covered by wind blown ash, the ashfall here is almost devoid of dust and fine particles, being composed of fragments of pumice heavy enough to be relatively little affected by air currents. The total amount of ash (about one inch) was so slight as to do practically no damage in itself. And, at first sight, we were inclined to conclude that the vegetation in this area was in no way injured by the eruption, but closer examination indicates that the bare places on the tops of a number of high knolls are probably results of the blast. There are a few groves of dead trees which, being exposed toward the volcano, likewise find their most reasonable explanation in the blast.

Photograph by R. F. Griggs

ALDERS ALMOST DESTROYED BY HAVING THEIR BUDS KILLED.

The cambium was everywhere alive and wherever a bud escaped it grew out with undiminished vigor. Russian Anchorage, July, 1913.

ZONE OF HEAVY ASHFALL.

We come now to the consideration of conditions in the fifth zone where the vegetation, in addition to being swept by the blasts already discussed under the preceding heading, was deeply buried under an ashfall so heavy as to prevent the restoration of an herbaceous ground cover. Concerning the conditions of death in this area but little needs to be added to what has already been said in the preceding section, for the working of the added agent of destruction is so simple as to require no particular exposition.

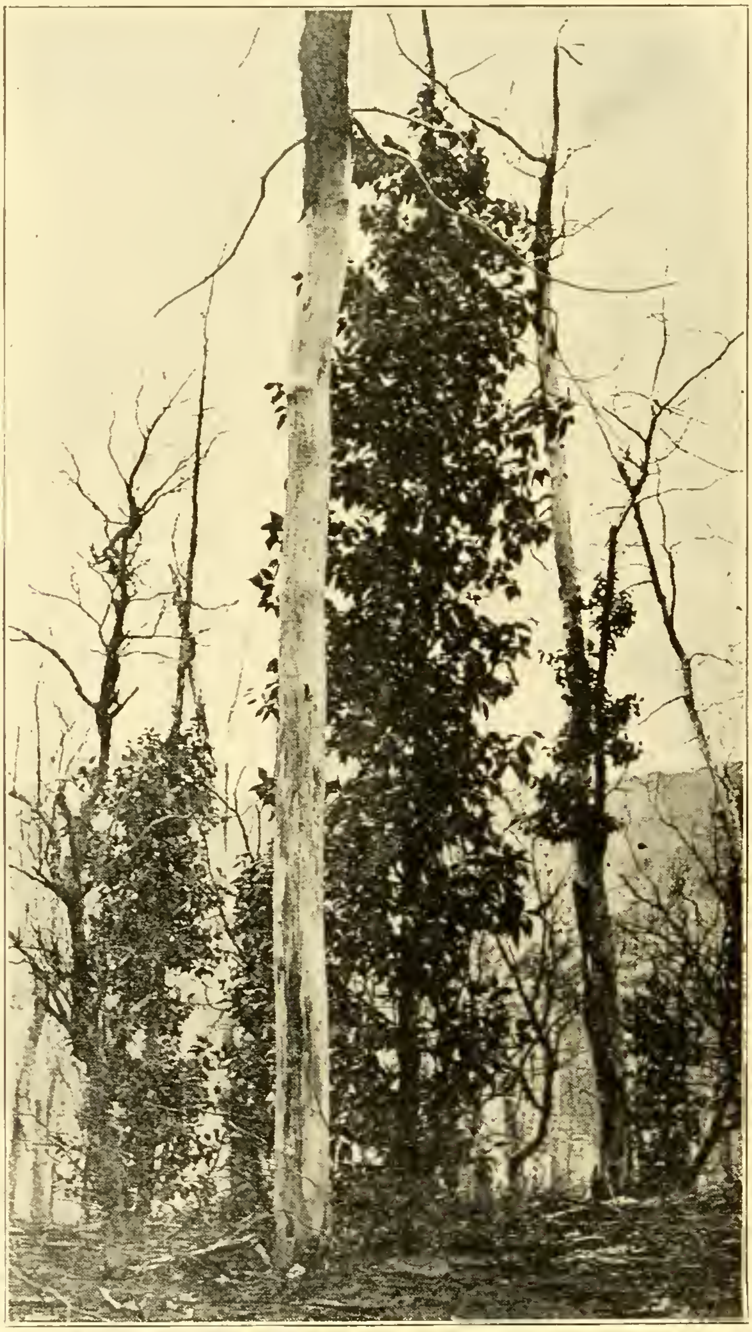
Photograph by R. F. Griggs

INJURED POPLARS IN LOWER KATMAI VALLEY.

The branches and ordinary buds were all destroyed. The new growth has come from dormant buds protected by a heavy growth of bark on the large branches.

Curiously enough the chief interest in this zone lies, not in the death of those plants which perished, but in the circumstances surrounding the survival of the few that persist. For these not only bear upon our original problem, that of revegetation, but also throw some interesting side lights on the character of the eruption.

Inasmuch as the area near the volcano was not visited until three years after the eruption, the observations concerning these survivals were perforce made on plants which had begun to recover. The data are, therefore, somewhat complex, including, beside the effects of the eruption proper, secondary effects partly direct consequences of it and partly subsequent restorative reactions of the plants. It will be advisable, first, simply to describe the present condition of the vegetation, after which some attempt may be made to analyze the data with a view of ascertaining what occurred in the eruption and what reactions the plants have made since.



Photograph by R. F. Griggs

IN MANY CASES LARGE TREES PERISHED WHERE SMALL ONES SURVIVED.

See text page 199 for explanation.

PRESENT CONDITION OF SURVIVING TREES.

Because of the difference in the habit of growth, the survivals among the various species of trees show quite different degrees of injury. Balsam poplars (*P. candicans*)* were the only large trees. All of the growing parts and all of the ordinary buds of these were killed; but some of the dormant buds, buried deep in the thick bark of the large branches, survived and have grown out forming short, bushy brushes, which give the trees a most outlandish appearance. (See page 185.)

In some places it may be seen that the smaller trees survived where the taller ones, standing beside them, perished. The taller trees were, of course, more exposed, and protected the smaller to a certain extent, but it is not obvious at first why their own lower branches, which were protected to the same extent as the adjacent saplings, have not survived. (See page 186.) Sometimes only a few buds on a very large tree have survived. The most extreme case of this sort of thing observed is shown on page 192. In other cases the bark is all dead except for a very narrow strand up one side of the tree which supplies the few new branches. (See page 198.)

The alder, (*A. sinuata*), which is the most characteristic Alaskan bush everywhere, was simply exterminated. Not until we had explored a considerable part of Katmai Valley did we find so much as a single live sprig of alder, and then we saw only two or three small shoots coming up from the roots.

The birch, (*B. kenaika*), the Alaskan representative of our paper birch, has suffered only less severely than the alder. Throughout the main valley it was destroyed, but in the more sheltered conditions of Soluka Valley new sprouts from the roots are fairly abundant.

The Alaska willow, (*Salix alaxensis*), suffered less than any other tree. In many places it has, in fact, almost completely recovered from the effects of the eruption. This is probably due to its capacity for forming adventitious roots on burial. (See below, pages 200–202). The other willows, *Salix nuttallii*, *Salix barclayi*, and *Salix bebbiana* have also recovered to a considerable extent, though their new growth is much less luxuriant than in *Salix alaxensis*. *Salix nuttallii* in particular shows an interesting reaction of tops as well as roots. (See page 201.)

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* The writer wishes to extend his thanks to Messrs. Paul C. Standley and A. S. Hitchcock of the National Herbarium, who kindly verified the determinations of the plants collected.

Photograph by R. F. Griggs

A DEVIL CLUB GROWING THROUGH THE ASH,

This plant has developed the "two storied" root system, characterisric of the buried vegetation. One set is just beneath the surface, another in the old soil. The three layers of the ashfall show well. Lower Katmai Valley—ashfall 20 inches.

HERBAGE INJURED LESS THAN TREES.

Beneath the trees, the ground is for the most part absolutely bare. Wherever the ashfall amounted to three feet or more nothing could come through. Apparently there were no surface cracks as around Kodiak. At least no evidence of them remains, and the ash near the volcano was so much coarser grained than that deposited at a distance that "mud cracks" would hardly be expected. Consequently, conditions were much less favorable for the penetration of the ash by the buried herbage. But, although the herbage was almost completely smothered by the ashfall, there is good reason to believe that it suffered less from the eruption itself than did the trees. While the trees remained exposed to the elements throughout the period of the eruption, the herbs were quickly covered with a protecting blanket of ash which shielded them from further injury. Where this blanket was later removed by the agents of erosion, the smaller plants have come up in their former profusion and are fruiting freely.

This is true throughout Katmai Valley. And even on the slopes of the volcano itself, every area bared of ash is occupied by plants which survived the catastrophe. *Wherever the ash covering has been removed, the old herbage has sent up new shoots.* On "Prospect Point" for example, a high rocky hill 500 feet up the slopes of the volcano, a few living plants were found in 1916 including the following: *Potentilla villosa* (in flower), *Salix arctica*, *Salix glauca*, *Rhodiola rosea* (flowering), *Carex sp.* (flowering), *Oxyria dignyia* (flowering), *Cerastium sp.*, *Heuchera glabra*, *Dryopteris droypteris*, three species of grasses, *Polytrichum* and another small moss. The particular species are, however, of little importance for the list includes most of the plants which happened to occupy the denuded area before the eruption. With the living were the dead remains of only three others, viz., *Alnus sinuata*, *Diapensia lapponica* and *Silene acaulis*. On the lowland a few hundred yards farther from the crater were found: *Calamagrostis langsdorfii*, (fruiting), *Carex sp.* (fruiting), *Equisetum arvense*, *Rubus spectabilis*, *Sanguisorba sitchensis*, and *Artemesia tilesii* (flowering). It could be plainly seen that many of these plants were new shoots coming from old roots present before the eruption. At another place about ten miles from the crater, where an upland bog happened to be so located as to be cleared of ash, the following have reappeared:

Athyrium cyclosorum, Trientalis arctica, Ledum decumbens, Betula rotundifolia, Empetrum nigrum, Vaccinium uliginosum (fruiting freely), *Cornus suecica* (flowering), *Vitis-idæa vitis-idæa.* And so, if one should take a census of the resurrected plants in various habitats, he could probably find representatives of most of the species in the flora.

Photograph by R. F. Griggs

EVENLY BEDDED STRATA OF KATMAI ASH LYING AS THEY FELL ON TOP OF A SNOW DRIFT.

The character of the contact and the absence of ice indicate that the ash was not hot as it fell. The blanketing of the ash prevented melting for five years. On Observation Mountain, only seven miles from the crater (June, 1917).

FALLING ASH RELATIVELY COOL.

The testimony of such plants shows that the explosion of Katmai differed markedly from many eruptions in the low temperature of the ejecta. In the case of Tarawera, for example, Pond and Smith[6] report that the ejecta retained a high temperature for a considerable time after they had fallen, and that the forest was consumed by fires, started presumably by the hot ash. If such conditions had accompanied the explosion of Katmai the evidence of them would be plain today. But nowhere is there any evidence of fire, neither charred wood nor indications that the buried trees and bushes were injured by the heat of ejecta coming from Katmai itself. On the contrary, wood of the buried bushes everywhere throughout this zone, even high up on the slopes of the volcano itself, is sound and well seasoned as though kiln dried.

The survival of the buried plants is even more significant evidence of the condition of the falling ash. Had the ejecta been hot as they fell, the deeper deposits would have cooled off very slowly and almost certainly would have cooked the plants beneath. The survival of plants under coverings up to 15 feet in depth would seem to demonstrate conclusively that the deposits could never have had a very high temperature.

Over large areas the ash fell on snowdrifts which, instead of being melted as they would have been by hot ejecta, were insulated by the thick mantle of ash and have persisted until the present time. The picture on page 190 shows a cavern caused by local melting of such a snowdrift which remained unchanged for five years after the eruption. The strata of ash lie as smoothly over the snow as over the bare ground, and there is not the least indication of irregularities due to superficial melting caused by the heat from the ejecta.

The low temperature of the ash is probably connected with the character of the ejecta, which are composed of exceptionally small fragments. There were no bombs of solid lava nor even large pieces of pumice thrown out from Katmai itself. All the ejecta are the type of frothy pumice and the largest lumps seldom reach ten inches in diameter. The finely fragmental character of the ejecta would operate in two ways to reduce the

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[6] Pond and Smith. On the Eruption of Mt. Tarawera. Trans. New Zealand Institute, 19 : 362, 1886.

temperature which probably was very high before the explosion. First, smaller particles would be cooled more rapidly in their journey through the air. This would be much more important at a distance than on the slopes of the volcano. Second, the expansion incident to the conversion of the magma into frothy pumice would absorb much heat and reduce the temperature. This is probably the more important factor near the vent.

Photograph by R. F. Griggs

A TALL POPLAR ON WHICH ONLY A FEW BUDS SURVIVED.

It seems incredible that so slight a leaf surface should have sufficed to keep the extensive trunk and roots alive for four years (July, 1916).

ALL SPECIES SUFFERED ALIKE.

All subsequent observation confirms and strengthens the point made in the former report, (Griggs[2]), of the remarkable absence of specific effects of the eruption proper on different plants. So far as can be seen, most of the flowering plants suffered alike. Where any perished, most perished, and where any escaped, almost all escaped.

The marked differences shown in the recoveries of different species are traceable in almost every instance to some readily observable difference in habit or adaptation. Thus *Equisetum arvense* came through where nothing else could, not because of any greater toughness of constitution or greater capacity to endure burial, but because it could send out runners of a greater length than other plants. *Salix alaxensis* recovered better than the poplars, not because more hardy, but because of its capacity of forming adventitious roots which the poplars lacked. Where here and there a few plants survived in the region of total destruction, it was for the most part due not to superior resistance but to a fortunate location.

This point is well brought out by a comparison of the condition of certain of the surviving plants in Soluka Valley, where the ashfall was six feet, accompanied by a blast, and around Kodiak, where the ashfall was one foot without marked elevation in temperature. All of the species mentioned were common in both localities before the eruption.

SOLUKA VALLEY.	KODIAK.
Alnus sinuata (only one seen alive)	Not injured.
Equisetum arvense (scarce)	The most abundant survival.
Athyrium cyclosorum (thrifty)	No survivors observed.
Trientalis arctica (flowering)	No survivors observed.
Ledum decumbens (flowering)	No survivors observed.
Betula rotundifolia (thrifty)	Only occasional.
Empetrum nigrum (thrifty)	Very rarely survived, was ubiquitous.
Vaccinium uliginosum (fruiting)	No survivors observed.
Sanguisorba sitchensis (flowering freely)	Abundant.
Cornus suecica (thrifty)	Rarely survived.
Vitis-idæa vitis-idæa (thrifty)	Rarely survived.

Most of these plants were found on Soluka Creek in the upland bog from which the ash was cleared away, as mentioned above. The reason for the survival of these plants here, when they were practically exterminated around Kodiak, clearly lies not in any peculiarity of the species themselves, but in the accident of a favorable situation.

Photograph by D. B. Church

PATCHES OF RESURRECTED HERBAGE IN CLEARED AREAS.

Contrast the bare ground still covered with ash round about. The roots from which these plants grew up were buried for three years until the ash was swept away by the Great Flood of July, 1915.

Photograph by R. F. Griggs

DETAIL FROM THE PATCH OF RESURRECTED HERBAGE SHOWN ABOVE.

The high water mark of the flood, which washed off the ash after it had buried the plants for three years, is plainly shown by the line on the bank and on the trees. The vegetation comprises a considerable number of species, see text page 196.

PLANTS WHICH LAY DORMANT FOR THREE YEARS.

At first it was supposed that such recoveries of buried herbage could occur only when it was exhumed soon after the eruption, for it did not seem possible that plants could survive burial for many months. But the observations of 1916 showed that this supposition was incorrect, for it was found that in many places where the ash had lain undisturbed for three years, until removed by the great flood of July 1915, plants from the old roots had come up in all their original vigor, forming in some places a rank and thrifty growth. (See pictures opposite). When first observed, an effort was made to interpret these patches in some other way than as survivals of such prolonged burial. It was first thought that the areas must have been uncovered at an earlier date, for it appeared incredible that they could have withstood a burial of three years. But some of the areas were so associated with high water marks many feet above the valley, that could only have been made by the great flood, the date of which was known, that the duration of the period of burial became a certainty. It was then thought that the rich soil exposed by the flood might have served simply as a favorable substratum on which wind distributed seeds had started, while they failed on the adjacent banks of ash. But this hypothesis was rendered untenable when it was observed that this new growth appeared only in places where the *original* surface of the ground had been left undisturbed by the flood waters. Wherever the wash had been stronger, so as to carry off not only the ash layer but also the surface soil with its included seeds and remnants of vegetation, the bared areas, although as rich as the surface soil, remained for the time, practically barren.

The condition of the plants themselves was more positive evidence, however, for it admitted of only one interpretation. The new growth could be traced in most cases directly back to the old stocks grown before the eruption. Associated with these were, in many instances, the much weathered remains of the growth before the eruption, but no remains of growth of intervening years, such as would undoubtedly have been present had any shoots appeared in those years, were noticed. No plants were found which showed any indication of growth for several years back.

Finally, crucial proof of the ability of the underground parts of plants to retain their vitality when buried was furnished at Kodiak when I found an old rhizome of Equisetum, which I had exposed in excavation in 1915, that had put forth new shoots the following year, as detailed in the first paper of this series, this journal page 32.

The plants which had thus recovered after having lain dormant for three years beneath the ash covering were some of the most characteristic species of the region, including: *Calamagrostis langsdorfii* (fruiting), *Equisetum arvense, Carex sp.* (fruiting), *Rubus spectabilis, Salix sp., Rhodiola rosea, Sanguisorba sitchensis, Artemesia tilesii, Poa sp., Streptopus amplexifolius, Cardamine umbellata, Cerastium sp.,* and *Juncus sp.* With the root survivals were also numerous seedlings, sprung from seeds that had lain dormant under the ash. *Carex* and *Sambucus pubens* were abundant in all stations. *Polemonium acutiflorum* (from seed ?), *Geranium erianthum,* and *Heuchera glabra* were also found but less commonly.

CAUSE OF DORMANCY.

There is little reason for supposing that the species found as root survivals have any special ability to endure burial, or that others in the same areas had succumbed, leaving only the most resistent to survive. The areas in question were not large. If larger areas with more varied habitats had been exposed, the list of survivals would probably have been considerably increased. The fact that this ability to recover after such a period of enforced dormancy was shown by various species of plants, directs inquiry to the physical conditions of the environment which made survival possible. Unfortunately not enough is known of the environmental conditions to enable one to make any satisfactory hypothesis as to the causal factors, but some facts bearing on the situation may be enumerated. The first supposition would naturally be that a low soil temperature was the responsible factor. But the facts of the situation will hardly permit one to assign to it the principal role in this connection. It must be remembered that the Katmai district is south of the region where the soil is permanently frozen.

The August soil temperatures at a depth of 30 inches were found to vary from 38°–56° F. in different situations. The most common readings were about 43° F. as compared with air temperatures averaging about 50° F. Thus the temperature beneath the heavy ash blankets on the mainland may be presumed to be in the neighborhood of 40°. F, But the Equisetum at Kodiak, which revived on being dug up, had been buried only a few inches beneath the surface and must have been at a temperature well above the growth minimum for several months in each of the three years of its burial. Next to the low temperature, one thinks of desiccation as a means of maintaining a dormant condition in plants. But desiccation cannot have been a factor in this case for the country is notoriously wet. Indeed, the Equisetum had lain below the water table in all but the driest months of the year. One might go on and consider the possible lack of oxygen and other factors, but there was nothing in the field to suggest the action of such factors and no means available of estimating their probable effect.

There is some evidence that a similar dormant period may follow the shock of an eruption even in a tropical country, where the vegetation is not accustomed to such seasonal variations as the plants of the Katmai District are subjected to by the long winters. In the revegetation of Taal, which has been studied in more detail than that of any other volcano up to the present, Gates[7] found in October, 1913, nearly three years after the eruption, only three clumps of bananas and none of bamboo. But, "in April, 1914, bananas were fairly abundant and indicated quite well the positions of many of the former houses," while bamboo was also prominent. Brown, Merrill and Yates[8] furthermore submit evidence which indicates that a large proportion of the new vegetation of Taal may have come from old roots which lay dormant for a long period.

RESTORATIVE REACTIONS OF SURVIVING PLANTS.

From what has been said above, it is evident that those trees, which were not killed outright by the eruption, were so injured that the chances of their ultimate recovery must have appeared remote if they had been examined soon after the

[7] Gates, F. C. The Pioneer Vegetation of Taal Volcano. Philip. Journ. Sci. Ser. C, 9: 391-434. Pls. 3-10. 1914.

[8] Brown, Merrill and Yates. The Revegetation of Volcano Island, Luzon, Philippine Islands Since the Eruption of Taal Volcano in 1911. Philip. Journ. Sci. Ser. C, 12 : 177-248. Pls. 4-16. 1917.

Photograph by D. B. Church

A POPLAR IN WHICH A FEW TWIGS ARE KEPT ALIVE BY A NARROW STRAND OF BARK (concealed in picture).

All the rest of the bark has died of starvation and dropped off.

eruption. The problem which had to be met by these trees was to maintain the extensive system of uninjured roots and branches with almost no leaves until new growth could provide the leaf surface necessary to feed the rest of the plant. The capacity shown by some of the trees of adjusting themselves to such abnormal conditions is remarkable. The most extreme case was found on Soluka Creek where a tall poplar was dead except for a very few twigs in the top. (See page 192.) The bark of this tree, which was 41 inches in girth, was dead along two strips 6 and 4 inches wide, leaving two bands of living bark 15 and 16 inches wide and 40 to 50 feet high to be supported by only the handful of leaves at the top. In another case all the bark had dropped off except the narrow strip connecting with the new growth, (see page 198), leaving the tree apparently stripped when viewed from the other side. Since the side of the trees where the bark persisted bore no relation to the position of the volcano, there is no reason for believing that the rest of the bark was killed in the eruption, this only escaping. It is rather to be supposed that the remainder of the bark died of starvation for lack of ability to put forth leaves.

TREES STARVING FOR LACK OF LEAVES.

Along with instances such as the foregoing, where trees have managed to survive with very small leaf areas, are others where they have succumbed through inability to tide over the period intervening before an adequate number of leaves could be grown. On many of the poplars the new twigs, after growing for a little while, blighted and died. On such trees it could be seen that the twigs farthest from the roots were dying first, and many cases were seen where the new twigs close to the ground were continuing to thrive where those higher up had long since withered away. (See page 200). But in others, the whole tree had perished after a futile attempt at renewed growth. This blighting is interpreted as due to the breaking down of the conducting or root systems, which was in turn caused by malnutrition from the lack of leaves. In this is found the explanation of the survival of saplings where large trees perished, as noted above. The new leaves were able to keep the roots and bark of the sapling alive, but not sufficient to maintain the more extensive roots and tops of the large trees. Thus many trees, comparatively but little injured in the eruption itself, have died subsequently because of inability to make good the destroyed buds.

NEW ROOTS AT THE SURFACE OF THE ASH.

Those plants like the willows, which readily put out new roots, were at a considerable advantage in recovering from the eruption, as compared with those without this power, like the poplars. For such plants, by putting out new shoots at the surface of the ash and new roots just beneath, could start afresh on the same basis as young plants without the necessity

Photograph by R. F. Griggs

A POPLAR WHOSE NEW SHOOTS ARE BLIGHTING, BEGINNING AT THE TOP, BECAUSE OF STARVATION OF THE ROOT SYSTEM.

of carrying the over-extended tops and roots of the old trees. This is very conspicuous in many places where the Alaska willow (*Salix alaxensis*) grew among the poplars. In the course of three years the willow practically made good its losses and was as thrifty as ever, while the poplars were more dead than alive.

In places where the ash, after lying on the ground for some time, has been washed away by streams, exposing the buried parts of such trees, the difference between the willows and poplars is very striking. The dead poplar trunks stand as they were at the time of the eruption, but the willows have grown extensive systems of new roots. These are not distributed throughout the length of the buried stem but are almost confined to the region immediately beneath the former surface of the ash. (See page 202.) The advantage of the willow over the poplar is obvious. That these new roots were really the decisive factors in the survival of the willows is shown by numerous cases where trees which had survived burial had succumbed to the removal of the ash layer, with the consequent dislocation of the new roots.

This type of root reaction was not confined to the willows but was found in a number of other plants as well. In general it may be stated that the stems of buried plants either remained unchanged, or reacted in this manner, developing the characteristic two-storied root system. The plants in which this reaction was found were: *Salix alaxensis*, *Salix nuttallii*, *Salix glauca*, *Echinopanax horridum* (see page 188), *Calamagrostis langsdorfii*, *Betula rotundifolia* (feeble), *Rubus spectabilis*, *Vaccinium ovalifolium*, *Deschampsia cæspitosa*.

STEM REACTIONS.

The reactions of the aerial parts of plants remain to be considered. For the most part the new growth gives no indication that unusual conditions were introduced in burial beyond those incident to the merely mechanical action of the ash. But a few species show interesting reactions to burial. The most conspicuous case is the pussy willow (*Salix nuttallii*). Before the eruption this grew as an erect bush two or three meters tall. In many cases all parts above the ground were killed in the eruption, but new shoots have been put out from the surface of the ash. These show no tendency to form new branches like the original trunk, but spread out flat on the

Photograph by D. B. Church

THE NEW ROOT SYSTEM OF A WILLOW EXPOSED BY A SHIFT IN FICKLE CREEK.

To the left may be seen the surface of the ash, while the stream at the right has cut into the original soil. The new roots came out eight feet above the original root system. Note the absence of such roots on the poplars in the bank and the comparative insignificance of their new growth.

ground, forming a rosette or mat. (See below.) An investigation of the physiological causes by which this reaction is brought about would yield exceedingly interesting results if one could find the means of attacking the problem. A satisfactory solution should throw much light on the causes underlying the development of prostrate shrubs in general, such as the prostrate juniper of the north and the prostrate yew of our own woods, both forms being closely related to erect growing species.

Photograph by R. F. Griggs

Before the eruption *Salix nuttallii* grew as an upright tree. The tops were killed and the new growth forms prostrate mats on the surface of the ground.

ZONE OF INCINERATION.

We come now to the consideration of the final zone. Curiously enough, areas of complete sterilization in which all vestiges of life were consumed by fire occur only at one side of the volcano, being confined to the vicinity of the Valley of Ten Thousand Smokes. On the other side of the range in Katmai Valley there is, as already remarked, not the slightest evidence of fire in connection with the eruption. Since the ashfall is much greater on that side, one is bound to conclude that no fires occured in connection with the eruption of Katmai proper, but that the manifold evidences of intense heat to be found in the area northwest of the volcano were not due to agencies emanating from the crater of Katmai. As will be seen, this conclusion is supported by so much local evidence of a positive character in the area burned over that there can be little question of its correctness.

Throughout the upper portion of the Valley of Ten Thousand Smokes and its branches not a vestige of the vegetation which must once have covered it is to be found. So complete has been the destruction that no evidence of what happened to the plants remains to tell the tale. As we explored this district we were for a long time altogether at a loss to understand what had happened. We could not reasonably suppose that the area had been devoid of all vegetation before the eruption. Indeed, we knew that there were once good sized trees far up toward Katmai Pass. On the other hand, in the light of our acquaintance with conditions on the opposite side of the range, we were hesitant in hypothecating destructive agencies so intense as to eradicate the very evidence of their action. Nevertheless we could see plainly that over a considerable part of the area the gray-green sandstones had been burned to a brick red by the heat of the eruption.

It was not until we extended our explorations down toward the foot of the great mud flow that fills the valleys throughout this zone that we began to find evidence confirming the suspicions aroused by the absence of plant remains around its head. In its upper portion the mud flow is so thick that we could nowhere find a stream-trench or fault line sufficiently deep to expose the relations of the mud flow to the underlying original soil. But at its lower end, where it is thinner, there is abundant opportunity to observe its effect on vegetation.

Here the mud flowed down through the forest engulfing the trees that stood in its path. (See below). If one walks along the edge of the flow where its effect on the trees can best be observed he can see what happened in the clearest possible fashion. The trees and bushes everywhere show evidence of disturbance by the moving stream of mud, but there is no indication of such violent action as would have been left in the wake of a torrent of water, for none of the trees

Photograph by R. F. Griggs

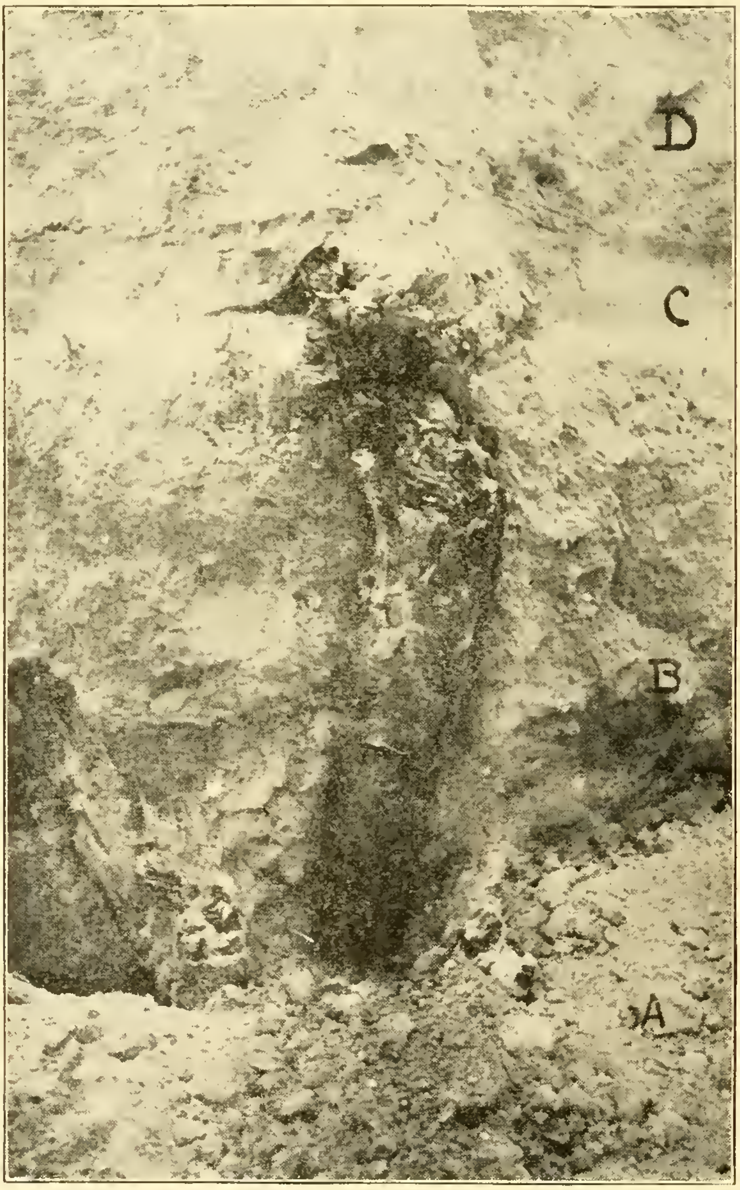
BURNED REMNANTS OF THE TREES ALONG THE EDGE OF THE MUD FLOW.

The trees on higher ground at the right, out of reach of the mud, though killed by the eruption, show no sign of fire. The mud flow, which so incinerated vegetation, was entirely independent of the explosion of Katmai. (See No. III of this series of articles).

are uprooted or broken up by the flow. In many places the tops protrude above the surface of the solidified mud. Such old tops are, however, but loosely held by the mud. If one takes hold of them they pull right out, when it is found that they are charred through about a foot below the surface.

The stream canyons in this district show abundant sections of the mud containing such trees. The charring action was so thorough that every particle of vegetation touched by the mud is completely reduced to charcoal. Some of the logs so charred are as much as a foot in diameter. (See below). In other places where the original ground has been uncovered by erosion, the remains of the mat of vegetation that covered it lie in place as a sheet of charcoal. (See page 207).

At a few places around this lower end of the mud flow the trunks of the trees standing above the level of the flow are scorched as though by a grass fire. But, for the most part,



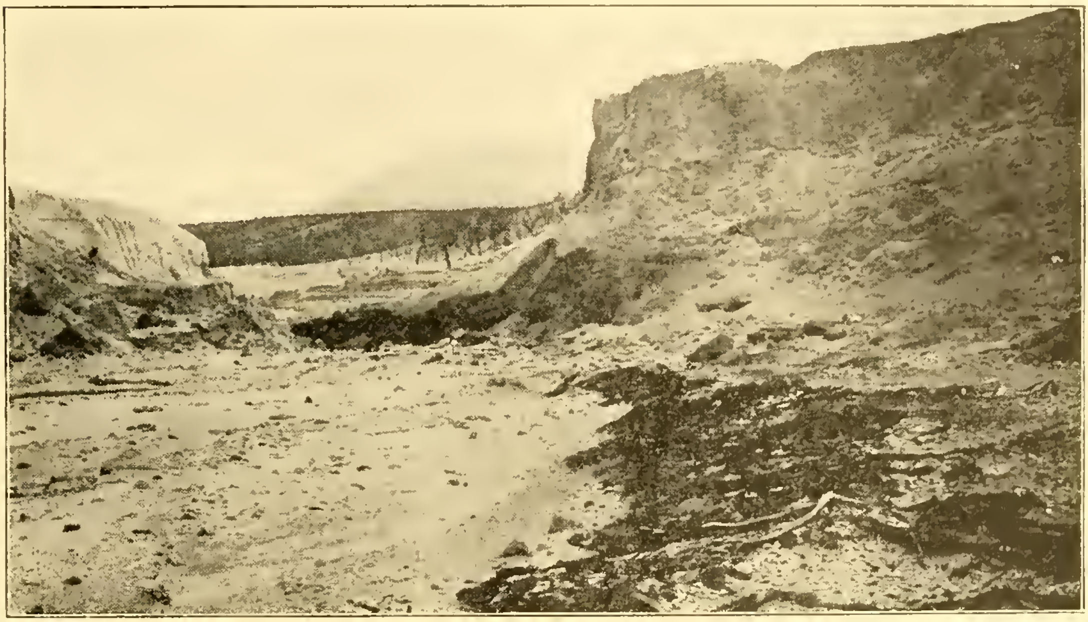
Photograph by L. G. Folsom

THE TRUNK OF A TREE ENGULFED BY THE MUD FLOW.

Although a foot in diameter, it was entirely reduced to charcoal by the heat of the mud flow. This section was found at the extreme limit of the zone of incineration, seventeen miles from the crater of Katmai.

no evidence remains to indicate the cause of the death of this forest. Its general aspect is much like that of the forests whose destruction has been attributed to blasts from the volcano, but differs in that here projecting shoulders of the mountains, etc., seem to have given little if any protection to the trees behind them.

Halfway up the Valley, however, we found a mountain-side which had every appearance of having been swept by a fire that had blackened the surface of all the remains of the vegetation, which had consisted of herbs and dwarf shrubs.



Photograph by R. F. Griggs

MAT OF VEGETATION REDUCED TO CHARCOAL BENEATH THE MUD FLOW.

The original surface of the soil has been uncovered by erosion.

This was the last sign of plant life found in the Valley, for further up the rocky hills were all absolutely devoid of plant remains. Unless they were originally totally barren, which seems impossible, they must have been so thoroughly burned over that all plant remains were consumed. While it may be somewhat uncertain how large an area was so completely sterilized as this, there can be little doubt but that such was the fate of all the district whose rocks were baked red by the heat.

One cannot consider these evidences of consuming heat without speculating as to the exact conditions under which it worked;

what the temperatures may have been; what chemicals may have been associated with its action; whether deadly fumes were given off along with the high temperatures; why charring was for the most part subterranean; why the destructive agencies were apparently more intense toward the head of the Valley; and a number of other similar problems. But these questions more properly belong to the geological discussion of the events of the eruption. They will, therefore, be passed over here and left for later discussion in their proper place.

The area included in this ultimate zone of complete annihilation is that of the basins in which fissure eruptions have occurred, namely, all of the valleys now occupied by volcanic vents and the upper part of Mageik Valley down to Observation Mountain, which is occupied by a mud flow similar to that of the Valley of Ten Thousand Smokes, and gives clear evidence of having been formerly the seat of fumarole action. Altogether this area of annihilation covers some 100 square miles.

Before concluding, it may be desirable to add a few statements concerning animal life, for in the zones of greater destruction the whole story may be told in a few sentences. In the last zone, all animal life was of course annihilated. In the district of deep deposits all animals were destroyed except for a few wood boring insects, which not only were protected by their habitats, but were furnished with an abundant supply of food in the trees killed by the eruption. Within the area of destructive blasts (Zone 4) the same condition prevails, but here one finds an increasing number of survivals favored by some special circumstance of habitat or situation.

SUMMARY.

The effect on the observer of a study of this stupendous eruption, as revealed by its effects on vegetation, is like that of any other consideration of its phenomena and serves greatly to augment his conception of its surpassing magnitude. Passing our results briefly in review will aid in giving a single concrete picture of this tremendous cataclysm, susceptible of comparison with other great eruptions.

1. Rains bearing sulphuric acid in such concentration as to destroy gardens occurred as much as 300 miles from the volcano.

2. An area of 7,300 square miles was covered with ash so deeply as to destroy the smaller plants.

3. Death-dealing blasts from the volcano killed trees 25 miles away, destroying the forest over an area of more than 1,500 square miles.

4. Ashfall, so heavy as to obliterate all herbaceous plants except on steep hillsides, etc., covered an area of about 970 square miles.

5. Mud flows so hot as to reduce to charcoal all vegetation with which they came into contact were poured out over an area of about 53 square miles.

6. An area of about 39 square miles, in which there is no trace of former vegetation, was probably swept by fires of great intensity, making the total area in which all life was annihilated 140 square miles.

THE TAXONOMIC POSITION OF MYSMENA BULBIFERA (GLENOGNATHA BULBIFERA) BANKS, WITH SOME OBSERVATIONS ON ITS HABITS.

W. M. Barrows.

During last summer, while making a study of the grassland spiders in the vicinity of Columbus, Ohio, I had occasion to observe the habits of *Mysmena bulbifera* Banks with some care. The observations made at this time raised the question whether this species could belong to the Family *Therididæ*, and whether or not it had been properly placed in the genus *Mysmena*. Subsequent study of specimens and field observations have shown that these spiders are clearly related to the *Tetragnathidæ* and that they should be placed in the genus *Glenognatha* of Simon. Evidences other than those of an anatomical kind will appear from the activities mentioned below. The reasons for making this change based on structure may be briefly stated.

In the original description of the genus *Mysmena* Simon, the anterior eyes are described as being subequal, in a slightly procurved line, the middle little separated from each other, *but contiguous with the lateral* (medii inter se angusti separati sed a lateralibus contigui). The legs are mentioned as being *short, tarsus* and *metatarsus about equally long* (Pedes breves, tarsis metatarsique circiter aequilongis). Actually the middle eyes are close together, but are widely separated from the lateral, the legs are rather long, with the tarsus only five-eighths as long as the metatarsus. On the other hand, my specimens agree very well with Simon's description of *Glenognatha*. The venter of the male is clearly cut transversely by a deep groove though it is probably not as deep as in the type species *Gelnognatha emertoni*. The palpal organ (Fig. 1) agrees well with the Figure of the type specimen given by Banks (Proc. Acad. Nat. Sci. Phila., April, 1913, Plate XII, Fig. 22). My specimens seem to be rather closely related to Bank's *Glenognatha minuta* (Proc. Cal. Acad. Sci., Vol. I, No. 7, 1898, p. 248).

Glenognatha bulbifera is a rather small pink and silver spider sometimes marked with black. It is rather common in the meadows and waste lands around Columbus, where it builds its delicate orb web in grass or weeds in rather hot dry situations. Usually the web is placed horizontally about two inches above the ground. The strands are so delicate that it is usually entirely overlooked. Near sunset, however, on finding the proper angle, the rays of the sun will reflect from its surface and make it easy to determine that the web is about four and one-half inches in diameter. The spiral strands are very close together and clearly hold drops of viscid silk. Blades

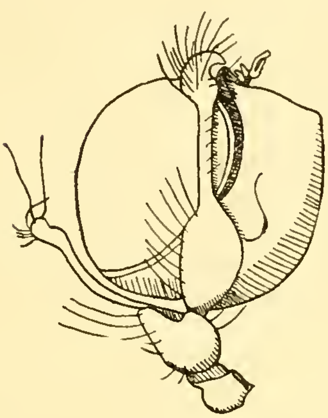


Fig. 1

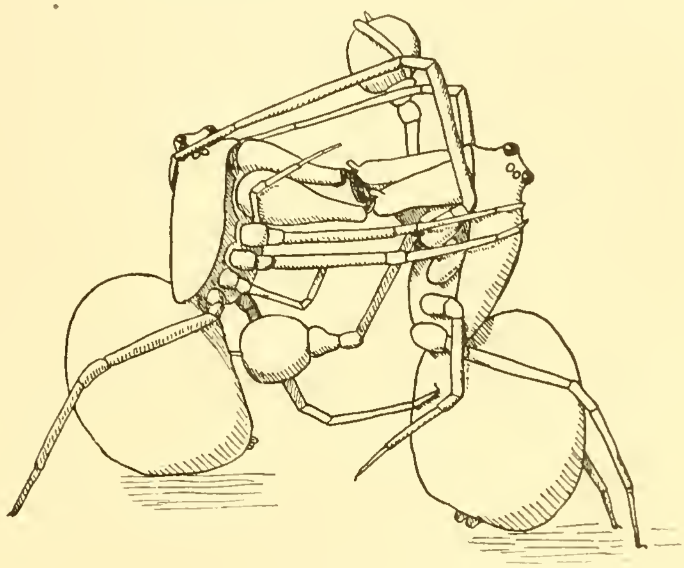


Fig. 2

of grass and other vegetation may grow up through the web apparently without causing its owner any uneasiness. The spiders, both males and females, remain on the under side of the web at its center unless disturbed when they drop to the ground and run rapidly away. If a vibrating forceps is touched to the edge of the web the spider orients and runs rapidly to the spot touched. If the forceps is withdrawn, the spider returns to the center. Mating occurs in June at the center of the web, both individuals hanging head downward. The male seeks the female and apparently can distinguish other males or females only by their reactions to his advances. I have seen two males fight for some time at the center of the web until the intruder was driven off and made to drop to the ground. When a male approaches a female, however, he is immediately seized. The two lock mandibles and grasp each other with their legs, venter to venter. The male inserts the palpal organs alternately keeping each inserted for perhaps five minutes, (Fig. 2). The accompanying Figure was sketched from a pair which mated in a vial and consequently does not show them in the usual position upside down. This copulation occupied about fifteen minutes, during which time each bulb was inserted twice. At the end of fifteen minutes the female shook the male free, but showed no animosity toward him, either at the time or later.

The fact that these spiders build an orb web excludes them from the Family *Therididæ.* Of the orb-weavers which use a viscid silk on the spiral threads there are only two families, the *Tetragnathidæ* and the *Epeiridæ.* The method of copulation observed in this species, corresponds closely with that observed in *Tetragnatha extensa* and *vermiformis*, and *Pachygnatha listeri* as described by Montgomery, Emerton, Menge and others. These species belong to the Family *Tetragnathidæ.*

All things considered, *Mysema bulbifera* should, I believe, be placed in the *Tetragnathidæ* and should be known as *Glenognatha bulbifera* (Banks).

I am very much indebted to Mr. Banks for verifying my identification of *Mysmena bulbifera*, and to Dr. F. E. Lutz, for sending me copies of the original descriptions of *Mysmena* and *Glenognatha* which were not within my reach.

Date of Publication, February 10, 1919.

V. THE NITROGEN CONTENT OF VOLCANIC ASH IN THE KATMAI ERUPTION OF 1912.

J. W. Shipley,
Chemist of the 1917 Expedition.

The opportunity to study the revegetation of a large area buried by volcanic ash comes but rarely. When in June, 1912, following several explosive eruptions, Mt. Katmai ejected from its crater about five cubic miles of ash and pumice and distributed it over the adjacent region to a depth of fifteen feet, gradually diminishing until at Kodiak, 100 miles to the eastward, it covered the island with a layer of fine ash ten inches deep, such an opportunity was presented on a scale unequalled by any volcanic eruption since the dawn of interest in such matters. All vegetation near the volcano was smothered and killed, leaving large areas covered with a finely divided soil which, while perhaps containing the mineral requisites necessary for plant growth, was absolutely free from organic matter and micro-organisms. An abundant rainfall, and climatic conditions favoring the growth of a diversified flora, made this region a fertile field of observation. Flanked on the south and west by the abundant pre-eruptive flora, while here and there throughout the destroyed area oases of plants are preserved, this barren area will become, in time, again clothed with vegetation.

The several expeditions of the National Geographic Society, sent out under the direction of Dr. R. F. Griggs, had as their primary object the observation of the revegetation of this remarkable region. It soon became apparent that one of the principal controlling factors, in the revegetation problem, was the supply of nitrogen as a necessary constituent of plant growth. Consequently the 1917 expedition was equipped with the necessary materials and apparatus for making field determinations of the ammonia and nitrite nitrogen content of the ash, and for collecting samples with a view to further analysis in the laboratory. This work was placed in charge of the author.

The nitrogen supply for plants attempting to gain a hold upon this otherwise fertile soil was made the subject of special study. Not only were observations made upon the water soluble ammonia and nitrite content of the ash, but determinations of the total nitrogen content of the volcanic detritus were made in the laboratory upon all representative samples. Determinations were also carried out upon the pre-eruptive soil so far as the tundra may be considered as representing it, and in addition a series of observations was made upon the nitrogen content of the rainfall and upon the water derived from melting snow.

Photogragh by D. B. Church

A CHEMICAL LABORATORY IN THE KATMAI REGION.

Only a chemist can understand the difficulties of making quanitative analyses where one must carry his laboratory on his back.

Ammonia nitrogen was determined by color comparison with a standard ammonium chloride solution, using Nessler's reagent in 50 cubic centimeter Nessler tubes about 25 centimeters high. Nitrous nitrogen was determined by comparison with a standard solution of sodium nitrite, using Griess's reagent in the above mentioned Nessler tubes. These reagents were prepared according to the directions outlined in the

A. P. H. A. Standard Methods of Water Analysis, and were carried to the field in small reagent bottles provided with a special device to guard against leakage or contamination. No attempt was made to use a set of standard colors, but each determination was matched against standard solutions. On returning to the laboratory the reagents and standard solutions used on the expedition were checked up, and, in the case of the nitrous nitrogen, a suitable correction for deterioration in the standard solution of sodium nitrite was applied to the observations. A copper still was carried into the field, but fortunately the use of distilled water was obviated by the almost complete absence of ammonia and nitrous nitrogen in the surface and spring waters of the Katmai district. Moreover, the water from melting snow was found to be almost free from these nitrogen compounds. (For a detailed statement of these matters, see the following paper of this series, pages 230–234).

The samples of ash investigated were air dried on aluminum plates, and 100 grams weighed on a small hand balance. This amount of ash was then placed upon a previously well washed filter paper in a five inch glass funnel, and leached with successive portions of ammonia and nitrite free water until approximately 150 cubic centimeters of filtrate were obtained. This filtrate was then made up to 150 cubic centimeters and 50 cubic centimeter portions used for comparison with the standard solutions. A check on the results was always kept by testing for ammonia 50 cubic centimeters of the last washings of the filter paper previous to adding the ash. It was really surprising how persistently traces of ammonia clung to the filter papers. Moreover the ubiquitous ammonium compounds were constantly being met with in the most unexpected quarters, and the greatest care had to be exercised in preventing contamination of the samples collected for analysis. On one occasion several samples of dry ash were carried to camp in ordinary brown paper bags that had not previously been used in any way. Irregularities in the analyses of the ash taken from these bags led to the suspicion that even the dry ash had been contaminated by contact with them. A water infusion of the paper bags, when treated with Nessler's solution, gave a heavy yellow precipitate of the ammonia complex. Ever afterwards all samples were collected and carried in glass or metal containers previously well freed from ammonium compounds by efficient washing.

Table I contains the results of the analysis of a seven-foot deposit of the volcanic ash in position. A mountain stream, undermining the deposit, exposed the horizontal layers as a cut bank, and this bank was cut into with a spade for over three feet and samples taken from the exposed vertical section. The analyses are the average of several closely agreeing results, excepting for the determination of total nitrogen. No. 6 is the average of two determinations.

The total nitrogen was determined in the laboratory on ten gram samples of the air dried ash by a modification of the Kjeldahl process. The diluted contents of the digestion flasks were made alkaline by ammonia free sodium hydrate solution

TABLE I.

Nitrogen Content of Katmai Ash from a Deposit, Seven Feet Deep, on Observation Mountain, About Eight Miles South of Katmai Crater.

	Parts Nitrogen per 100,000		
	NH_3	NO_2	Total N.
(1) Wind drifted layer, 4″ deep	none	none	.....
(2) Top dust layer, 2″ deep	none	none	.....
(3) Yellow layer, 10″ deep	0.001	none	.....
(4) Gray layer, 32″ deep	0.001	none	.....
(5) Terra cotta layer, 16″ deep	0.001	none	.....
(6) Lower gray layer, 18″ deep	0.002	none	.....
Mixed sample of all the above	.....	.....	0.005

and made up to 200 cubic centimeters. Fifty cubic centimeter portions were then compared in Nessler tubes with standard ammonium chloride. Blanks, treated exactly as the ash samples, were run concurrently, and the ammonia content of the blank subtracted from that of the ash.

The lower layers of the ash deposit contained large pieces of pumice. These were discarded and the analysis made on the finer material. The relatively large ammonia content of the lower 18-inch layer may be attributed to contact with the pre-eruptive surface on which it rests. The upper layers have lost, presumably to the atmosphere, what little ammonia they may have possessed. It may be that all of the ammonia found in the ash has percolated upwards from the pre-eruptive soil, but the quantity is so small that it might equally well be considered to have come in rainwater. The eruption was accompanied by very heavy downpours, which would wash down not only the normal amount of nitrogenous products in the air, but also any gaseous nitrogen products of the eruption. The small total nitrogen content of the ash precludes any possibility of the vegetation securing its nitrogen supply by any conceivable decomposition of the volcanic detritus. The material deposited by the Katmai Crater came from the igneous complex, and probably does not contain any of the sedimentaries of the region through which the volcanics extrude. Sandstones of this period, according to Stewart and Peterson[1], contain as

TABLE II.

NITROGEN CONTENT OF ASH FROM VARIOUS LOCATIONS.

	Parts Nitrogen per 100,000		
	NH_3	NO_2	Total N.
(1) Wind blown ash, water saturated, on top of snow bank	none	none	.....
(2) Wind blown ash, behind Camp IV, Observation Mountain	none	none	.....
(3) Caked top layer ash on Observation Mountain, north of Camp IV	0.004	none	.....
(4) Moist ash, similar to (3)	0.004	0.0004	.....
(5) Ash one foot beneath (4)	none	none	.....
(6) Sample similar to (3)	none	none	.....
(7) Sample similar to (3)	none	none	.....
(8) Ash along spring stream in which algae were growing, Observation Mountain	0.002	0.00004	.....
(9) Ash four inches beneath (8)	0.004	.....	.....
(10) Ash, Katmai Mud Flow, Katmai Volcano	none	none	none
(11) Top layer ash, Katmai Volcano	trace	0.00004	0.80

high as 65.5 parts per million of nitric nitrogen alone. The total nitrogen content of the Katmai volcanic ash is but 0.05 parts per million.

Table II contains observations made on surface samples of ash taken from the immediate neighborhood of the Volcano. Little or no ammonia and nitrous nitrogen were found. Algæ were observed growing in the ash at the base of Observation Mountain where a small spring arose. Determinations (8) and (9) relate to this ash. The complete absence of nitrogen from the sample of the Katmai Mud Flow is comparable to that of the volcanic ash included in Table I, for the Katmai Mud Flow is

[1]Stewart, Robt. and Peterson, Wm. The Nitric Nitrogen Content in the Country Rock. Utah Agriculture College Experiment Station. Bull. 134. June, 1914.

most probably a composite sample of the ashfall, formed by the slumping of large masses down the slopes of Katmai immediately following the eruption. The analyses listed in Table II were made upon representative samples of the surface ash contaminated very little, if at all, from the pre-eruptive soil. There may have been some admixture however, for the strong winds of this region drift the ash for long distances, and have laid bare the old soil on the exposed ridges and hills. The relatively high total nitrogen content of (11) might well be due to wind borne humus from the old soil, that found lodgment for the time being upon the moist top layer of the finely divided Katmai ash.

TABLE III.

Nitrogen Content of Some Miscellaneous Samples of Ash.

		Parts Nitrogen per 100,000		
		NH_3	NO_2	Total N.
1917. Aug. 15.	(1) Katmai River wash, seedling grass growing; cf. (5), pp. 226 and 229....	0.04	0.0004	3.20
	(2) Same, and close to (1), but seedlings died; cf. (6), pp. 226 and 229........	trace	trace	3.20
Sept. 15.	(3) Kodiak Island, Pillar Mountain, Vegetation Station No. 14; cf. (4), pp. 226 and 229........................	0.012	trace	0.80
1916.	(4) Sample 33, Katmai Church, stream borne; cf. (1), pp. 226 and 229......	.....	.....	6.40

The analyses included in Table III were made for the purpose of ascertaining whether the nitrogenous plant food in the ash was the determining factor controlling vegetation. The results must be interpreted in conjunction with the ferrous iron and free acid content of the same samples included in another paper[2], although the nitrogen content of (1) and (2) is very small and any difference appears to be in favor of (1), yet in the light of the ferrous iron content the difference in vegetative growth must be attributed to the well known toxic effects of this compound. The ash designated by (3) in the table was a wind blown drift on the flank of Pillar Mountain, Kodiak Island, on which, after five years, little or no vegetation had returned. Free sulphuric acid and ferrous sulphate were found in this sample also, but not to the same injurious extent

[2]Shipley, J. W Scientific Results of the Katmai Expeditions. VI. The Water Soluble Salt Content, the Ferrous Iron Content and the Acidity of Katmai Volcanic Ash. Ohio Journal of Science, 19: 224-229, 1919.

as in (1) and (4). Sample 33, collected by Dr. Griggs in 1916, was found to contain twice as much total nitrogen as (1), in which seedling grass was growing, but the acidity and ferrous sulphate content was so high as to preclude the possibility of plants surviving.

Martin Creek, the principal affluent of Katmai River, flows in from the west and brings the drainage waters from

TABLE IV.

NITROGEN CONTENT OF RIVER DEPOSITED PUMICE AND ASH, KATMAI RIVER, MARTIN CREEK CAMP.

1917		PARTS NITROGEN PER 100,000		
		NH_3	NO_2	Total N.
July 1.	(1) River deposited ash, *Lupinus nootkatensis* in blossom	0.02	0.00018	.....
July 2.	(2) River deposited ash, *Lupinus nootkatensis* in blossom	0.032	0.00018	.....
July 2.	(3) River deposited ash, three foot radius from (1)	0.024	0.00016	.....
July 2.	(4) River deposited ash, three foot radius from (2)	0.026	0.0002	0.88
July 2.	(5) Mixed sample from around several lupine roots	0.02	0.00026	.....
July 2.	(6) Mixed sample from around several lupine roots	none	0.0002	.....
July 2.	(7) Sample of ash, etc., two feet beneath (1)	0.028	0.0001	.....
July 2.	(8) Brown humus soil, lupines growing	0.02	none	.....
Aug. 15.	(9) Ash among roots of lupines, near spring north of Martin Creek	0.006	0.00006	.....
Aug. 15.	(10) Ash among roots of lupines growing farthest out on ash deposited by Katmai River	0.006	0.00004	0.50
Aug. 15.	(11) Ash around roots of ripened lupines	0.002	0.00006	.....
Aug. 16.	(12) Martin Creek, black sand, lupines growing	trace	none	.....
Aug. 16.	(13) Ash bed of creek below spring, near trail, sickly grass seedlings	0.004	0.00004	.....
Aug. 16.	(14) Old soil surface, many plants growing	0.004	0.00098	.....

the southerly slopes of Mt. Martin and Mt. Mageik. This area was to the windward of the Volcano at the time of the eruption and consequently received but a slight fall of ash and pumice. The pre-eruptive vegetation along its head-waters still persists, and the frequent floods coming down throughout the summer might be expected to scatter this vegetation far and wide over the everchanging ash and pumice bars of the lower Katmai Valley. Just below the junction of Martin Creek with Katmai River lies an extensive flat covered by river borne wash of ash, pumice, and black sand. The latter comes from the glaciation of the volcanic slopes of Martin and Mageik, and with the great flood of 1915 became mixed in all proportions with the ash and pumice of the upper Katmai, and spread along the western side of the river valley. Towards the river the black sand content gradually diminishes until the soil becomes a pure mixture of ash and pumice. The loose texture of this river deposited material was in striking contrast to the finely divided, compact ash of the lower stretches, and offered a soil where physical conditions appeared ideal for the growth of seedling plants. Nevertheless the only plant taking advantage

Photograph by R. F. Griggs

A LUPINE GROWING ON THE ASH FLAT.

Although the soil is almost devoid of nitrogenous compounds as shown by the analysis, the lupines thrive and produce seed in abundance.

of these conditions was a legume, *Lupinus nootkatensis.* These plants were quite numerous and apparently were normal and healthy, having produced an abundance of ripened seed by the middle of August. Those growing farthest out on the ash were somewhat stunted in growth, but this was not to be wondered at considering that they had to withstand the buffetings of many a fierce sandstorm in which their lower leaves were cut to pieces by the sharp wind-driven volcanic ash. All of the lupines examined had an abundance of nodules on their roots. These must have been the source of their nitrogen for there was nothing like sufficient total nitrogen, much less water soluble nitrogen, present in the ash for the sustenance of the plants. Here we have Hellriegel's famous pot experiments carried out by Nature in the field on an extensive scale. Cultivated soils seldom have less than 100 parts per 100,000 of total nitrogen in the surface foot. Here the total nitrogen content was less than one per cent. of this amount, and the water soluble ammonia and nitrite content almost nil. The presence of healthy lupines growing far out on this ash flat clearly indicates that all of the essential plant constituents were present in the soil, while the absence of all other varieties of plants pointed to

Photograph by R. F. Griggs

THE PUMICE FLAT ON WHICH LUPINES ARE STARTING.
The dark spots right and left are lupine plants similar to that shown close up on the opposite page. The entire absence of all other vegetation is very striking.

the lack of some essential constituent of plant growth. This essential was no doubt nitrogen. The lupines were doubtless provided with their necessary nitrogen by symbiotic relations with the nitrifying bacteria in the nodules.

The first four determinations in Table IV show that the growing plants have not altered the ammonia and nitrous nitrogen content of the ash. Those determinations on the original black soil, where plants were growing in profusion, indicated almost the complete absorption of all the ammonia and nitrous nitrogen. The total nitrogen of these latter samples would of course have shown a total nitrogen content comparable to that of (13), Table V.

That the lupines were not found growing in profusion up over the ash covered hills is probably due to the lack of inoculation with nitrogen fixing bacteria of any seeds that may have found their way onto the surface. The river bed ash has been water transported and thus probably become inoculated with bacteria from the pre-eruptive soil, but the ash upon the hillsides is lying as it fell five years ago.

TABLE V.

Nitrogen Content of Tundra, Kashvik Bay, Alaska.

1917		Parts Nitrogen per 100,000		
		NH_3	NO_2	Total N.
June 20.	(1) Surface sample among roots...........	0.120	none	.....
June 20.	(2) Sample 6″ beneath (1).................	0.240	0.0012	.....
June 20.	(3) Sample 18″ beneath (1)................	0.240	0.0012	.....
June 21.	(4) Surface sample among roots...........	0.360	none	.....
June 21.	(5) Sample 8″ beneath (4).................	0.060	0.0006	.....
June 21.	(6) Sample 24″ beneath (4)................	0.120	0.0006	.....
June 21.	(7) Northerly slope. surface among roots.	0.096	none	.....
June 21.	(8) 15″ beneath (7). Tundra frozen below	0.160	0.0002	.....
June 21.	(9) 18″ beneath (7). Frozen tundra.......	0.064	0.0004	.....
June 22.	(10) Sample from hollow in tundra, bare of vegetation.........................	0.180	none	.....
June 22.	(11) 18″ beneath (10). On surface of sandstone rocks........................	0.162	none	.....
Aug. 22.	(12) Surface sample of tundra..............	0.160	trace	.....
Dec. 19.	(13) Sample from first foot of tundra.......	.....	.....	432.0

THE NITROGEN CONTENT OF ALASKA TUNDRA.

An opportunity for studying the nitrogen content of the tundra was offered at our Base Camp on Kashvik Bay. The tundra here is very shallow, seldom more than a couple of feet in depth, and rests upon the decayed sandstone rocks of Jurassic age. Small depressions occur at intervals, exposing the sandstone rocks below. Clumps of cottonwood and alder stretch up the mountain slopes, while down toward the sea the tundra is almost bare of large shrubs, but covered with a more or less rank growth of grass and small flowering plants. Narrow, invisible streams cut the tundra to the sandstone bed and run down to the sea.

The ammonia content of the tundra is about that of a normal soil. Ordinary soils contain little ammonia, usually from 0.2 to 0.8 parts of nitrogen per 100,000. Rich garden soils may contain up to 2 parts per 100,000, while Boussingault reports 50 parts in leaf mould from South America. Peat has been found to contain as high as 18 parts per 100,000.

The nitrite content is much higher than that found in the samples of ash. The surface tundra has no nitrites, as was to be expected in an area well under-drained and subjected to frequent rains. The nitrite forming bacteria do not operate near the surface but are found in the deeper, darker layers. The presence of much vegetable matter in the tundra, upon which the nitrifying bacteria may work, accounts for the greater proportion of nitrous nitrogen over that found in the ash.

On the northerly slopes the winter frost had not left the tundra by June 21st. Determinations made on the frozen tundra did not indicate any marked difference between its ammonia and nitrous nitrogen content and that already thawed out. Nitrification is rather feeble at temperatures below 5° C, and only begins to be really active at 12° C. A determination made on August 22nd gives no indication of any material change in the rate of nitrification with the season. Evidently the cold condition of the tundra produced no change in the nitrite content throughout the long frozen period.

The total nitrogen content of the tundra, 432 parts per 100,000, is considerably higher than that of the average cultivated soils. Illinois prairie soils contain 308 parts per 100,000, while the abnormally high nitrogen content of the rich black loam of the Red River Valley, in the neighborhood of Winnipeg, contains but 373. This large total nitrogen content is probably associated with a low rate of nitrification in the cold, shallow soil of the tundra.

Manitoba Agricultural College, Winnipeg.

VI. THE WATER SOLUBLE SALT CONTENT, THE FERROUS IRON CONTENT AND THE ACIDITY OF KATMAI VOLCANIC ASH.

J. W. Shipley,
Chemist of the 1917 Expedition.

Certain samples of Katmai volcanic ash collected by Dr. R. F. Griggs in 1916 were found by him not to support the growth of plants, but on the contrary apparently to have a toxic effect upon germinated seedlings. Qualitative tests made by the author upon these samples indicated the presence of ferrous sulphate together with a decided acidity in the water extract. During the expedition of 1917 other samples of ash were collected from deposits upon which vegetation had secured a more or less precarious hold, and in which field observations showed acidity in conjunction with the presence of ferrous iron. These samples were analyzed with the object of ascertaining whether the acidity and ferrous iron content was sufficient to account for the apparent sterility.

Sample No. 1. Stream deposited ash from near Katmai Church at the mouth of Katmai River, collected in 1916. Sample 33, Vegetation Station No. 102. Wheat germinated, but the seedlings quickly became malformed and never appeared above the surface. For determination of nitrogen content, see page 218.

Sample No. 2. Katmai Mud Flow on Katmai Volcano, collected in 1916. By itself it was toxic to wheat, but this toxicity was removed when it was mixed with coarse sand.

Sample No. 3. Katmai Mud Flow, collected in 1917.

Sample No. 4. Pillar Mountain Station, Kodiak Island. Vegetation Station No. 14. Collected in 1917. Plants not growing.

Sample No. 5. Katmai River mud, deposit above Camp II. Seedling grass growing. For nitrogen content see page 218.

Sample No. 6. Similar to No. 5, and close to it, but seedling grass had died. For nitrogen content see page 218.

The analysis was carried out on 100 gram samples of the air dried ash. This amount of each sample was placed on a filter paper in a funnel and lixiviated with successive portions of hot water, until the filtrate approximated 500 cubic centimeters. This water extract was then made up to exactly 500 cubic centimeters and 100 cubic centimeter portions used for the analysis. The acidity was determined by titration against N/100 NaOH and calculated as H_2SO_4, the ferrous iron by titration against N/20 $KMnO_4$. The ferric iron was also determined in Samples No. 1 and No. 6 by reduction with zinc and sulphuric acid and titration against $KMnO_4$. The

Photograph by D. B. Church

FLOOD BORNE SILT AROUND KATMAI CHURCH.

This appeared to be a favorable situation for the beginning of revegetation, but it was found by experiment that the soil was toxic to wheat plants. The analysis showed 0.558% of ferrous iron.

increase in the amount of $KMnO_4$ used in this titration, over that in an equal volume before reduction, gave a measure of the ferric iron. The water soluble sulphate was also determined in these two samples by precipitation as $BaSO_4$. The accompanying table contains the results of the analysis.

Ferrous sulphate is not only directly injurious to plant growth, but by inhibiting the action of nitrifying bacteria indirectly cuts off the supply of an essential food. The presence of this toxic compound, together with the low nitrogen content of the Katmai ash, will militate strongly against the revegetation of the areas affected. Ferrous sulphate in the presence of water hydrolyzes, giving ferrous hydroxide and sulphuric acid. Nitrifying bacteria do not thrive well in a strongly acid medium. The presence of 1.35% FeO ($FeSO_4$ calculated as FeO) kills all nitrifying bacteria, while 0.3%, according to Storer[1], is very injurious. Voelcker found that 0.5% $FeSO_4$ did much harm to plants, while 1.0% killed entirely.

TABLE I.

WATER SOLUBLE FERROUS IRON CONTENT AND ACIDITY OF KATMAI VOLCANIC ASH.

SAMPLE NO.	1 %	2 %	3 %	4 %	5 %	6 %
Acidity as H_2SO_4.....	0.215	0.020	0.014	0.003	0.025	0.057
Ferrous Iron as FeO..	0.558	0.063	0.040	0.081	0.180	0.270
Ferric Iron as Fe_2O_3.	0.037	.....	.....	.....	.....	0.025
Sulphate as SO_4......	0.300	.....	.....	.....	.....	0.081

The toxic effects of Samples No. 1 and No. 6 are no doubt attributable to the ferrous iron content, while Sample No. 5 is probably a poor soil for the growth of most plants. In fact, the seedling grass observed on it was far from healthy and strong. A low nitrogen content, of course, would prevent any rank growth, and this Sample No. 5 also possesses. The Katmai Mud Flow does not possess sufficient ferrous sulphate to injure plant development and consequently, as Dr. Griggs found, wheat would germinate and grow when the ash was brought into proper physical condition by the addition of coarse sand.

The soluble sulphate content of the samples analyzed is not sufficient to combine with all the iron present. There was a certain amount of chloride present in the samples, but a quantitative estimation of this acid radical was not made. The ratio of sulphate to iron in the two samples analyzed is practically the same.

The presence of water soluble ferrous iron in the above samples is probably directly attributable to the volcanic origin of the ash. Ferrous iron in marshland and moors is attributed to the reducing action of algæ upon sulphates, but here, although the soil was wet, algæ were not in evidence to any extent, and surface water conditions could hardly be considered as stagnant.

[1]Storer, F. H. Agriculture in Some of its Relations to Chemistry. Vol. 2, page 209. 1906.

The conditions of the eruption were reducing, and sulphuretted hydrogen, together with hydrochloric acid, are still important volcanic emanations of this region. The ash contains considerable quantities of ferrous iron, and this acted upon by the acid fumes would give water soluble ferrous iron. Some of the streams leaching the slopes of Mt. Katmai are strongly impregnated with alum, indicating plenty of sulphates in the ash deposit. The finely divided, water deposited ash of Samples No. 1 and No. 6 are very compact and practically impervious to atmospheric oxygen; consequently the iron has had little opportunity to pass to the ferric condition. Moreover, the absence of humus and of soluble calcium salts prevents the fixing of the toxic ferrous iron into compounds non-injurious to plant growth.

Numerous observations in the field showed that ferrous iron and acidity were always associated with finely divided, river deposited ash saturated with water. This formed a compact impervious mass, through which an exchange of water soluble substances would not occur; for, being saturated from below, any rainfall on its surface immediately runs off without appreciably affecting the content of the mass. Even the ash deposit on Pillar Mountain, although wind deposited, was nevertheless of this character, for it was very finely divided and saturated from the seepage of the hill upon which it rested. All deposits of the ash, where composed of coarser materials, were found to be free from water soluble ferrous iron and sulphuric acid. This was no doubt due to efficient drainage, with consequent aeration and prevention of the accumulation of these toxic compounds.

THE WATER SOLUBLE SALT CONTENT OF KATMAI VOLCANIC ASH.

The water soluble salt content of a number of samples of the Katmai volcanic ash was determined by the Electrical Bridge, according to the method recommended by Davis and Bryan[2], for the determination of alkali in soils. The measurements were carried out on samples of the ash, treated with distilled water, until just a little more than saturated. The instrument used was the latest form of the Electrical Bridge, as described by Davis and Bryan in the above mentioned bulletin, and the calculations for the salt content from the Bridge readings were based on their factor 1.45 as the ratio

[2]Davis, R. O. E. and Bryan, H. The Electrical Bridge for the Determination of Soluble Salts in Soils. U. S. Dept. of Agriculture, Bureau of Soils, Bull. 61. 1910.

of soil resistance to solution resistance. The use of this factor was made necessary since the table of resistances and salt content did not cover the whole range desired. A series of resistances for sodium chloride solution, ranging from 0.5 grams to 2500 grams per 100,000 of water was determined on the Bridge, and by using the factor 1.45 and interpolating, the results given in Table II were obtained. No great degree of accuracy is claimed for the results, but the measurements are roughly approximate, and give some idea of the soluble salt content in the volcanic ash deposits. Included in the table are two

Photograph by R. F. Griggs

DEPOSIT OF BARE ASH ON PILLAR MOUNTAIN, KODIAK.

Determinations of ferrous iron, acidity, soluble salt content, ammonia, nitrite and total nitrogen content of this ash were made.

measurements made with the same instrument on arable soil, the samples being representative of the first six inches. The Katmai River wash, where finely divided, contains a much higher salt content than the normal soil or the coarse deposits, such as those of the Martin Creek flat. The ash from the wind blown drift on Pillar Mountain contains very little soluble salt content, a factor possibly entering into the non-fertility of this deposit. The two samples from the Katmai Mud Flow show very little variation, although a twelvemonth elapsed between the collections. The very fine upper layer of ash, as collected from the slopes of Katmai, shows a relatively high water soluble content, 39.2 parts per 100,000. This finely divided, compact layer does not leach out so readily as the coarse material of the lower layers, and consequently will hold its salt content more tenaciously.

A comparison of the total water soluble salt content, as determined by the Electrical Bridge, with the ferrous iron content, as determined by successive leachings and titration with $KMnO_4$, shows a wide divergence in the cases of Sample 33 and the Pillar Mountain drift. The total water soluble content does not nearly approximate the ferrous iron content as calculated from the reducing property of the leachings. This would

TABLE II.

Soluble Salt Content of Katmai Ash. Calculated from the Electrical Resistance.

	Resistance at 60° F. Ohms	Calculated Salt Content per 100,000 Grams
(1) Sample 33. Stream deposited ash, Katmai Church. Wheat would not grow	256	92.0
(2) Katmai Mud Flow. 1916	684	29.1
(3) Katmai Mud Flow. 1917	673	30.0
(4) Ash, Pillar Mountain Station, Kodiak	4218	5.7
(5) Katmai River wash. Seedlings growing	162	195.0
(6) Katmai River wash. Seedlings died	136	230.0
(7) Sample 37. Generalized sample of ash as it lay on the ground after three years weathering, Kodiak, August, 1915	196	160.0
(8) Sample 38. Wind blown ash, collected in attic, Kodiak	388	53.5
(9) Ash from around roots of lupine, Martin Creek flat	1344	15.6
(10) Top layer ash, 2000 feet up Katmai Volcano	558	39.2
(11) Tundra, Kashvik Bay	826	19.0
(12) Red River Valley black loam, timothy growing	445	48.2
(13) Red River Valley black loam, oat field	515	43.0

indicate that the ferrous compound, whatever it may be, either does not go readily into solution or does not dissociate. The agreement between the results in the case of the remainder of the samples included in Table I and those in Table II is much closer. Although a considerable range of water soluble salt content in the various samples of ash is seen to exist, yet the divergence from that of a normal soil is not so marked as one might expect, the content from the normal soils listed lying intermediate between the extremes of the ash samples. Even the high water soluble salt content of (1), (5), (6) and (7), in Table II, is not so high as that of some alkali soils on which crops grow and mature.

Scientific Results of the Katmai Expeditions of the National Geographic Society.

VII. AMMONIA AND NITROUS NITROGEN IN THE RAIN WATER OF SOUTHWESTERN ALASKA.

J. W. Shipley,
Chemist of the 1917 Expedition.

While engaged in the work of the 1917 Katmai Expedition of the National Geographic Society, directed by Dr. R. F. Griggs, opportunity was afforded for making observations on the ammonia and nitrite content in the rainfall of Katmai and adjacent districts. Determinations were made on the Bering Sea side of the peninsular axis, on the Pacific slope, and on Kodiak Island, 100 miles to the eastward. The most extended series of observations was made at our Base Camp on Kashvik Bay, during a very rainy period from August 19th to August 27th. This constitutes the major part of the work done and the results, together with those of Kodiak Island, are to be found in the accompanying Table. Kashvik Bay is on Shelikof Strait, about 25 miles due south of Katmai Volcano and the same distance southeast from the Valley of Ten Thousand Smokes.

The chemical reagents, brought with the expedition for determining ammonia and nitrites in the volcanic ash, were equally well adapted for measuring the same nitrogen bearing compounds in rain water. Ammonia was determined by color comparison with Nessler's reagent, using a standard solution of ammonium chloride. The nitrites were compared with a standard solution of sodium nitrite through Greiss's reagent, (a naphthylemine and sulphanilic acid). These solutions were prepared according to the A. P. H. A. Standard methods of Water Analysis. On returning from the expedition the standard solutions were compared with freshly prepared solutions of the same salts, using the reagents brought back from Alaska. The NH_4Cl proved to be unchanged, but the $NaNO_2$ had decomposed 50%. A sample of the same nitrite solution, as taken on the expedition, but left in a dark cupboard in the laboratory, had also decomposed to the same degree. The solutions were prepared May 16, 1917, and were compared on December 19th, seven months later. A comparison made on May 22, 1918, showed a further decomposition amounting to an additional 15%. Assuming that the decomposition followed the law of mass action, corrections were applied to the field determinations, and the results tabulated are the corrected observations.

The necessity for preparing distilled water was fortunately obviated by the almost total absence of either nitrous nitrogen

TABLE.

Ammonia and Nitrous Nitrogen In Rain Water of Southwestern Alaska.

Place	Collection	Analysis	Parts Nitrogen per 100,000		Remarks
			NH_3	NO_2	
Base Camp Kashvik Bay					
(1)	Aug. 19	Aug. 22	trace	0.0008	Stood in covered aluminum pail.
(2)	Aug. 15–22	Aug. 22	0.03	0.001	In brass rain gauge for almost a week.
(3)	Aug. 19	Aug. 25	trace	0.0004	Same sample as (1).
(4)	Aug. 25	Aug. 25	trace	0.0003	Rain gauge ¾″ fall. N. E. storm.
(5)	Aug. 25	Aug. 25	trace	0.00035	Glass funnel and Nessler tube.
(6)	Aug. 25	Aug. 25	trace	0.00016	Later in day, rain gauge.
(7)	Aug. 25	Aug. 25	trace	0.00011	Same time as (6).
(8)	Aug. 26	Aug. 26	trace	0.00012	Funnel, in morning.
(9)	Aug. 26	Aug. 26	none	none	Funnel, in afternoon near end of rain.
(10)	Aug. 25–26	Aug. 26	0.0015	0.00016	Rain gauge, storm from over Shelikof Strait.
(11)	Aug. 27	Aug. 27	none	0.0003	Funnel, ¼″ fall, no wind.
(12)	Aug. 27	Aug. 27	none	0.00018	Rain gauge, same as (11).
Kodiak					
(13)	Sept. 15	Sept. 15	trace	0.00014	Off metal roof, N. E. Storm.
(14)	Sept. 15	Sept. 15	trace	0 00016	Collected in aluminum pail.

or ammonia nitrogen in the spring and creek waters of the district, and in water obtained from melting snow. At Kashvik Bay no coloration whatever was produced by Nessler's reagent in the water from the creek. On adding to 50 cubic centimeters of the creek water 0.05 cubic centimeters of the standard NH_4Cl solution containing 0.00001 grams nitrogen per cubic centimeter, a distinct coloration was produced, and on diluting to half this concentration the solution was more strongly colored than an equal volume of creek water. A similar test, using the standard $NaNO_2$ solution proved the almost entire absence of nitrites in the water of the creek.

In addition to water collected in the rain gauge, use was made of an aluminum pail and glass funnels set in the mouth of 50 cubic centimeter Nessler tubes. The latter proved to be the most serviceable. The collections at Kashvik Bay were made over the tundra, not less than eight inches above the vegetation in the case of the funnels, and almost two feet in that of the rain gauge. The Nessler tubes were always rinsed with the first fallings. Excepting the rain gauge, collections were made to the windward of camp, and far enough removed to prevent the possibility of contamination from the occasional camp fire.

The two determinations made at Kodiak were during the progress of a heavy northeasterly storm, lasting the entire day. Sample (13) was collected about mid-day, while (14) represents all but the beginning of the rain. Due to the direction of the wind, no contamination from smoke was possible.

The first three determinations in the Table were made on samples standing for some time after collection. The high nitrite content of these three is probably associated with this long standing. The high ammonia content of (2) was the result of small twigs and pieces of bark, wind-driven into the exposed rain gauge during the previous week.

The almost entire absence of ammonia in the rainfall of southwestern Alaska is in striking contrast with that found at a similar latitude in Europe. The average of a number of observations in Scotland gave 0.61 parts of ammonia nitrogen per million on the seacoast, and 0.44 parts at inland country places, while Glasgow gave 7.49 parts per million. The highest observed at Kashvik Bay was 0.015, and in most cases there was but a mere trace if any. At the Experimental Station, Rothamsted, England, the average of ammonia nitrogen in rain water over a fifteen year period was 0.45 parts per million. Storer states that the average in regions where factories are absent is about 0.02 parts per million.

Nitrous nitrogen was positively present in every determination excepting (9). The presence of even the small quantity of nitrites represented by the Table, in the rain water of a region devoid of thunderstorms, is highly interesting. One might expect that all nitrites would be transformed into nitrates in the presence of such oxidizing agents of the atmosphere as ozone and hydrogen peroxide. But instead, nitrites were found to the extent of 0.0035 parts per million of rain water at the beginning of a rainfall.

The rainfall of August 25th-26th shows a gradual falling off in nitrite content as the storm progressed, until towards the end none was observed. The content in the rain gauge throughout the storm is the average of that found at the beginning and at the end, as well as the average of all five samples collected in the funnels. It is also to be noted that the nitrite content had again risen to the maximum in a quarter inch rainfall the very next day, while the ammonia content still remained at a minimum.

One further peculiar circumstance was observed, in that, on standing for about four hours in the Nessler tubes, the reddish color produced in the samples of rain water faded out, while those in the standard solution of creek water retained their color.

The observations made on the Bering Sea side of the peninsular axis were quite irregular in the amount of ammonia and nitrite found. The determinations were carried out at Camp V in the Valley of Ten Thousand Smokes, just at the western entrance of Katmai Pass. When the wind blew from over the Valley, the ammonia and nitrite content was relatively high, while only traces were observed when the storm was blowing into the Valley. The rainfall, when the wind blew from over the Valley, also contained notable quantities of chloride and sulphate, and at times was so strongly acid as to make the eyeballs smart. Samples of rain water were collected close to fumaroles, so that the rain fell through ascending gases. Many of these gave so much ammonia that a heavy yellow precipitate formed with Nessler's reagent. The quantity of nitrous nitrogen was also greater than in an ordinary rainfall, and one fumarole in particular gave a deep red color, indicating the presence of considerable quantities of nitrites in the gaseous emanation. Quantitative comparisons were not made excepting in the cases when the storm was blowing into the Valley. Here, as already stated, the ammonia and nitrite content differed but little from that observed at Kashvik Bay.

Water from melted snow was used for the standard solutions. The drip from the snow bank was remarkably free from ammonia and nitrites, although these were being poured forth from the millions of fumaroles in the immediate neighborhood. Air, laden with these products, was constantly in contact with the thin layer of ash above the snow, and the frequent rains must have carried them down into the snow beneath. Nevertheless, melted snow from the bank behind Camp V gave no positive test for either ammonia or nitrite during the whole month we were in the Valley. Rain Water collected above the snow bank, when the wind blew from over the Valley, gave considerable quantities of both. This freedom from ammonia and nitrites was also observed in water from a snow bank on Observation Mountain at the eastern entrance of Katmai Pass. Here the bank in question was covered by several feet of ash, and was highly discolored from the leaching due to frequent rains. This bank served as a source of water for the standard solutions used in the comparison cylinders at Camp IV. One possible explanation for the absence of these nitrogenous substances is the presence of organisms in the snow capable of utilizing the ammonia and nitrite content of rain water in their assimilative processes.

A sample of rain water collected by hanging an aluminum pail from the dead branch of a tree gave an unusually large content of ammonia. The only contamination apparent was the drip from a short section of this one small dry branch. Water, in which a few twigs broken from the same cottonwood tree were allowed to stand for a short time, gave a heavy yellow precipitate with Nessler's reagent, proving that the high result noted above came from ammonium or similar nitrogen compounds in the decaying wood. The soil must receive considerable additions of ammonium compounds washed down from decaying trees, and in this region, where the lack of nitrogenous material for plant growth is so marked, this source of nitrogen may have some little influence on the revegetation of the destroyed area.

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TWO NEW VARIETIES OF ACER RUBRUM L.*

FREDA DETMERS.

That the species of Acer are very variable is well known and that the variability has long been recognized becomes evident on examination of Pax's admirable and exhaustive monograph of the Aceraceæ, Engler and Prantl Pflanzen Familien. I have, therefore, hesitated to present two additional varieties of Acer rubrum. However, these two trees are so unlike any others I have seen, so unlike herbarium specimens I have examined and do not conform to any descriptions given, that I feel justified in describing and naming them as new varieties. As Acer rubrum is dioecious the staminate trees cannot or have not been verified.

Acer rubrum L. **var. viride** n. var.

Leaves thin, distinctly green on both sides, glabrous, glaucous underneath with a few hairs on the veins, rather small, 5.5–7 cm. long, by 7–8 cm. broad across the apices of the lateral lobes, 3-lobed with two smaller lobes near the base, lobes acute, distinctly triangular, margin irregularly serrate, base subcordate. The unfolding leaves somewhat yellow but never red. Petioles 3–3.5 cm. long, slender, tinged with red. Twigs reddish gray, glabrous. Bud scales red, glabrous, with green pubescent margins. Flowers of carpellate tree with red calyx and corolla, red stamens, green carpels with red styles. Mature samaras distinctly green with no trace of red, glabrous, rather dull, 1.2–2 cm. broad, 2–2.5 cm. long; wings short, broad, strongly nerved, contiguous or slightly divergent, seed cavity large, 8 by 10 mm., full and plump. Fruiting pedicels green, stout, 2.5–4 cm. long. Staminate tree unknown.

The type tree is on Cranberry Island, Buckeye Lake, Licking County, Ohio. It is a young specimen, about 9.5 m. tall with smooth light gray bark. It is surrounded by other Red Maples.

Type specimen in herbarium of the Department of Botany, Ohio State University. Paratype in the national herbarium, Washington, D. C.

The most striking feature of the tree is its greenness. The leaves develop early from 1–2 weeks before those of surrounding trees and are green as soon as they unfold. The samaras are

*Publication No. 102 from the Department of Botany, Ohio State University.

always green. The shape of the leaf resembles rather closely the more typical Red Maple leaf, but the Samaras in shape and color are quite unlike those of any other Red Maple.

Acer rubrum L. **var. rubro carpum** n. var.

Leaves large, 8–9 cm. long, 9–10 cm. broad across the apices of the lateral lobes, firm, green with red veins, glabrous above, glaucous underneath with cobwebby golden hairs on the veins; the three main lobes are broad, blunt, the terminal one oblong with distinctly parallel sides, each lobe is lobed again; margin sparingly dentate, teeth large; base of leaf subcordate with shallow sinus, almost truncate. Petioles red, stout, 6–7.5 cm. long. Unfolding leaves deep red, lower surface densely covered with reddish golden hairs. Bud scales deep red, margin lighter, covered with long interwoven golden hairs. One year old twigs red, glabrous, older ones reddish gray. Flowers of carpellate tree with brilliant rose calyx and corolla; stamens apparently fully developed, deep red, carpels with deep red ovularies and styles. Mature samaras glabrous, shining, deep purple red, with no trace of green; wings 2–2.5 cm. long, slender, straight, widely divergent, broadest at tip; seed cavity small and slender, 6–7 mm. by 4–5 mm. Fruiting pedicels 3–5 cm. long, very slender, deep red. Staminate tree unkown.

The stamens in the carpellate flowers contained apparently fully developed pollen, but it failed to germinate. Tree young, 8 m. tall, slender; bark smooth light gray. The leaves unfold later than those of the new variety *viride*, as can be seen by comparing the photos, both of which were taken May 11, 1918.

The deep red of the buds, young twigs, flowers, mature fruit and unfolding leaves make this tree conspicuous even among Red Maples. In general, proximity to the water on Cranberry Island causes a marked increase in anthocyan; but this tree stands quite near the center of the Island and is easily the reddest of all the trees.

The broad firm leaves resemble those of *A. drummondii*, but the samaras are entirely different.

Type tree Cranberry Island, Buckeye Lake, Ohio.

Type specimens in the herbarium of the Department of Botany, Ohio State University.

Paratype specimens in the national herbarium, Washington, D. C.

In order to show the characters which distinguish the above described varieties of Acer rubrum from the other species which most closely resemble them I append a key to the species of Engler and Prantle's section *Rubra* occurring in the United States.

Key to the Section Rubra of the Genus Acer in the United States.

Leaves simple, palmately lobed; flowers in lateral umbels opening before the leaves.

1. Petals absent; ovulary tomentose; samaras 5 cm. long or longer........... ....*A. saccharinum.*
1. Petals present; ovulary glabrous; samaras from 2-7.5 cm. long..............2
2. Samaras 4 cm. or more long; leaves large, firm, white tomentose beneath. .... *A. drummondii.*
2. Samaras less than 4 cm. long; leaves pale or white glaucous underneath, sometimes pubescent on the veins...................................3.
3. Leaves prevailingly 3-lobed, tips of lateral lobes curve forward; blade more or less pubescent underneath...........................*A. carolinianum.*
3. Leaves prevailingly though not conspicuously 5-lobed, glabrous or glaucous beneath...4.
4. Mature samaras shining, deep purple red, slender wings widely divergent more than 90°; leaves firm, veins and petioles dark red................ ....*A. rubrum var rubro carpum.*
4. Mature samaras green or yellow sometimes tinged but never wholly red; leaves variable...5.
5. Leaves and samaras green through all stages of development; samara short and broad, wings straight, broad, contiguous or nearly so; seed cavity broad and bulging.........................*A. rubrum var viride.*
5. Leaves and samaras more or less red; wings of samara always diverging, sometimes in curved, seed cavity slender................................6.
6. Samaras very small 2 cm. long strongly nerved..............*A. stenocarpum.*
6. Samaras more than 2 cm. long, not strongly nerved..............*A. rubrum.*

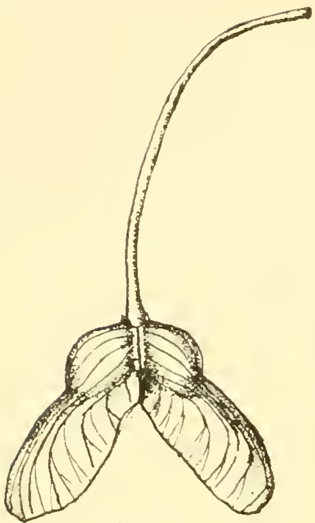
EXPLANATION OF PLATES.

Plate XII. *Acer rubrum* L. var. *viride* n. var.

Fig. 1. Mature samara. (Nat. size), collected May 18, 1917.
Fig. 2. Young leaf. (Nat. size), showing size and condition of leaves at the time when the fruit is mature. May 18, 1917.
Fig. 3. Mature leaf. (Nat. size), collected August 9, 1917.
Fig. 4. Photograph of the tree. May 11, 1918.

Plate XIII. *Acer rubrum* L. var. *rubrocarpum* n. var.

Fig. 1. Mature leaf. (Nat. size), collected August 9, 1917.
Fig. 2. Mature samara. (Nat. size), collected May 18, 1917.
Fig. 3. Young leaf, (Nat. size), showing size and very tomatose under surface of leaf at the time when the fruit is mature.
Fig. 4. Photograph of the tree, May 11, 1918.



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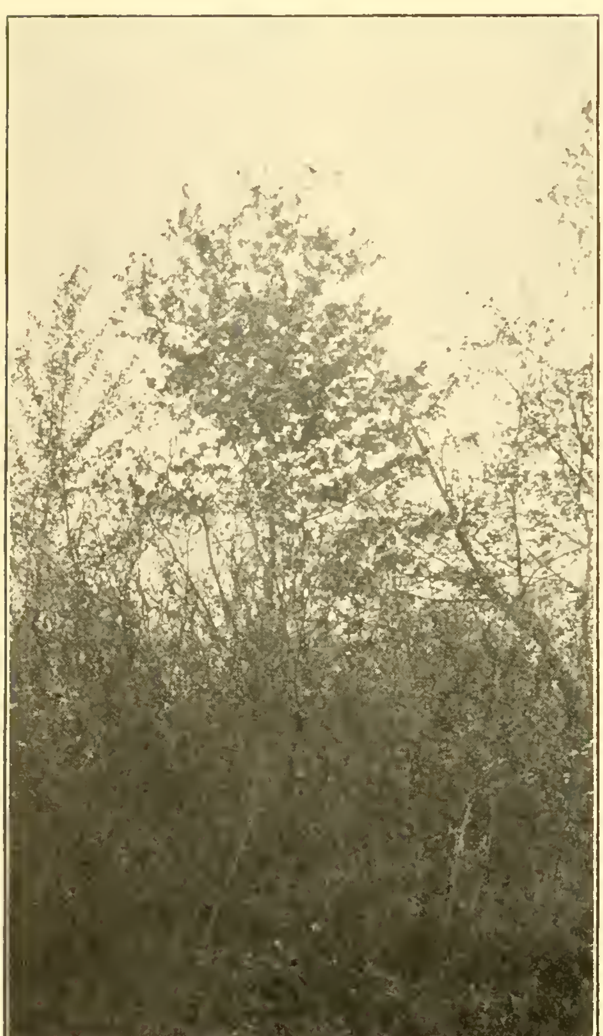

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Freda Detmers

NEW ŒDOGONIACEÆ.

E. N. Transeau and Hanford Tiffany.

The following forms of Oedogonium and Bulbochæte have been found in collections from Illinois and Massachusetts and are apparently undescribed.

Oedogonium hystricinum nov. sp.

Oedogonium dioicum, nannandrium, idioandrosporum; oogoniis singulis, globosis vel subobov iformibus, poro mediano apertis; oosporis globosis vel subglobosis, oogonia fere complentibus; episporio brunneo, echinis subuliformibus instructo; cellulis suffultoriis tumidis; plantis masculis paullo gracilioribus quam femineis; androsporangiis 3–6-cellularibus; cellula fili terminali obtusa; cellula fili basali elongata; nannandribus subrectis in cellulis suffultoriis sedentibus, antheridio exteriore, unicellulari;

Crassit. cell. plant fem.	8–15,	altit.	42–100
" cell. plant masc.	6– 9,	"	50– 67
" cell. suffult.	16–19,	"	42– 70
" oogon.	30–40,	"	36– 53
" oospor. (c. echin.)	23–38,	"	28– 43
" cell. androsp.	6– 8,	"	8– 15
" stip. nannandr.	6–10,	"	20– 32
" cell. antherid.	5– 6,	"	6– 10

Diœcious, nannandrous, idioandrosporous, oogonia single, globose or somewhat obovoid, pore median; oospores globose or subglobose, nearly filling the oogonia, outer spore wall, brown, densely covered with spines; suffultory cells swollen; male filaments smaller than the female; androsporangia 3–6-celled; terminal cells obtuse; basal cells elongated; dwarf males nearly straight resting on the suffultory cell, antheridium exterior, one-celled;

Diam. veg. cell. female plant	8–15,	length	42–100
" " " male plant	6– 9,	"	50– 67
" " suffult.	16–19,	"	42– 70
" " oogonia	30–40,	"	36– 53
" oospore (includ. spines)	23–38,	"	28– 43
" androsporangia	6– 8,	"	8– 15
" stipe, dwarf males	6–10,	"	20– 32
" antheridia	5– 6,	"	6–10

This species is near Oe. Hystrix Wittr. but differs in the small diameter of the filaments in proportion to their length and the size of the oogonia. The suffultory cells are swollen and the androsporangia are much smaller.

Collected from a temporary pond at the West end of Polk St., Charleston, Illinois, May, 1914. Type in herbarium. E. N. T. Collections. No. 2310, 2364. (Plate XIV, Figs. f-i.)

Oedogonium Pisanum gracilis nov. var.

Var. omnibus partibus gracilior; ceterum ut in typo.

Crassit. cell. veget. fem.	6– 9,	altit.	18–48
" cell. veget. masc.	5– 8,	"	16–45
" oogon.	16–20,	"	20–30
" oospor.	15–18,	"	18–28
" cell. antherid.	5– 7,	"	5–10

Diœcious, macrandrous; oogonia single, rarely 2, elliptical to elliptical-ovate, operculate, division superior; oospore elliptical nearly filling the oogonium, outer wall smooth; male filaments somewhat smaller than the female; antheridia 1–4 celled; sperms two, division horizontal; basal cell elongated; terminal cell hairlike;

Diam. cells of female plant	6– 9,	length	18–48
" cells of male plant	5– 8,	"	16–45
" oogonia	16–20	"	20–30
" oospores	15–18,	"	18–28
" antheridia	5– 7,	"	5–10

Somewhat smaller than the species in all dimensions, otherwise similar to the type.

Collected at Gates' pond, Coffeen, Illinois, May, 1914. Type in herbarium. E. N. T. Coll. No. 2420.

Bulbochæte Bullardi nov. sp.

B. dioica, nannandria, idioandrospora; cellulis vegetativis, diametro 2-8-plo longioribus; oogoniis ellipsoideis vel ovoideo-ellipsoideis, erectis, sub setis longis terminalibus, poro supramediano apertis, evidenter; oopsoris ellipsoideis, oogonia complentibus vel non complentibus; costis episporii dentatis, dentibus inter se costis transversalibus, evidentibus conjunctis; costis longitudinalibus irregulariter inter se anastomosantibus; 1–6 cellularibus; nannandribus paullulum curvatis, in oogonis vel cellulis suffultoriis vel cellulis vegetativis sedentibus; antheridio exteriore, 1–3-cellulari;

Crassit. cell. veget.	20–32,	altit.	60–165
" oogon.	56–66,	"	70– 96
" cell. androsp.	18–21,	"	15– 33
" stip. nannandr.	18–21,	"	30– 33
" cell. antherid.	9–14,	"	6– 10

Diœcious, nannandrous, idioandrosporous; vegetative cells 2–8 diameters long; oogonia ovoid-ellipsoid or ellipsoid, erect, terminated by a long seta, pore evident and supramedian; oospore filling or nearly filling the oogonium and of the same form, ribs of outer wall dentate, the teeth connected by transverse lines, longitudinal ribs uniting irregularly, androsporangia 1-6-celled; dwarf males slightly curved resting on the oogonia, suffultory cells, or the vegetative cells; antheridium exterior, 1–3-celled;

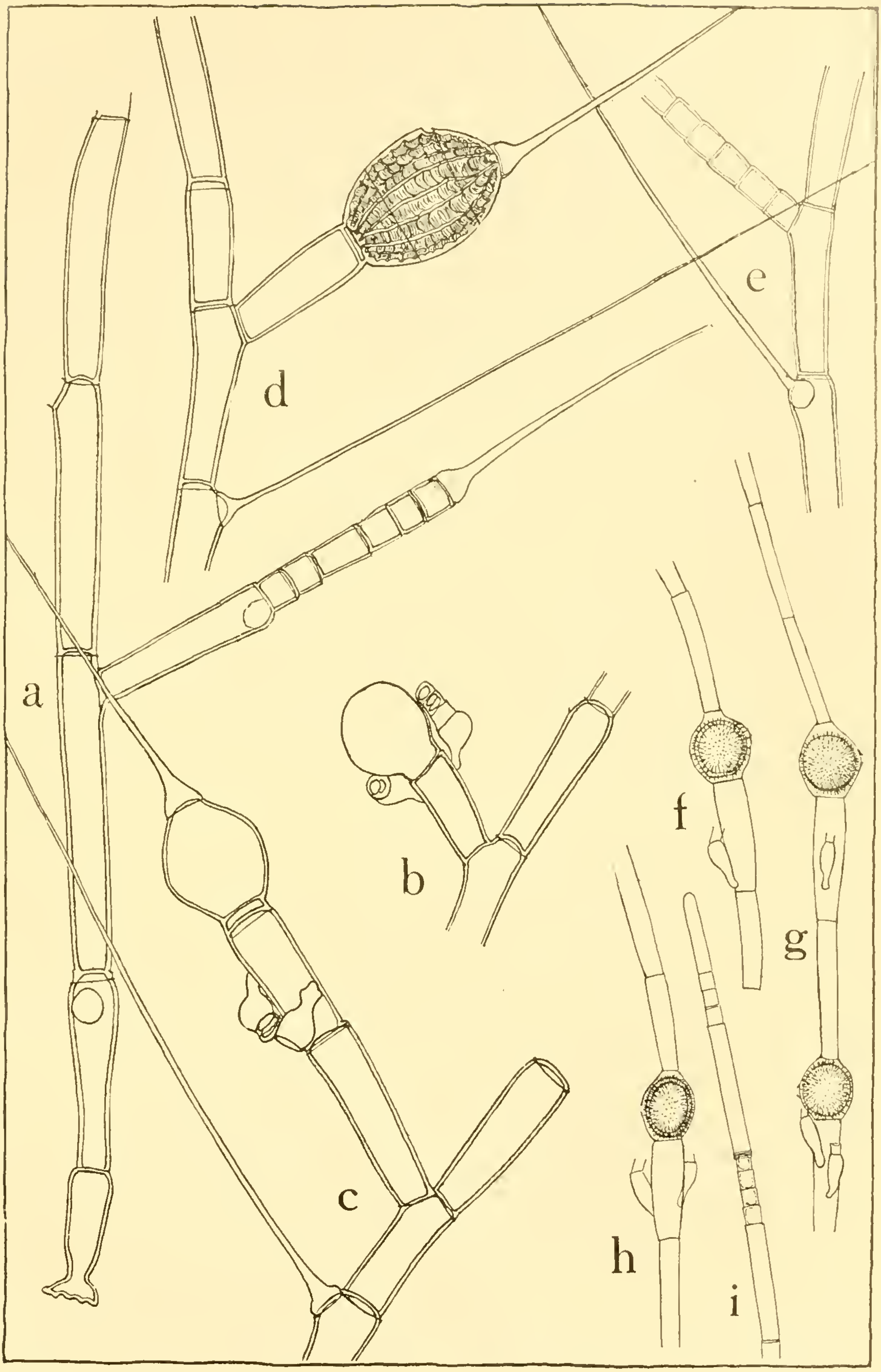
Diam. veg. cells	20–32,	length	60–165
" oogonia	56–66,	"	70– 96
" androsporangia	18–21,	"	15– 33
" stipe dwarf male	18–21,	"	30– 33
" antheridia	9–14,	"	6– 10

This species has larger vegetative cells than any of the described species. Its position in the genus is near *B. imperialis* Wittr., from which it differs in dimensions, in being idioandrosporous, and in the more highly ornamented spore wall. The spore most nearly resembles that of *B. insignis reticulata* (Nordst.) Hirn. Collected by Mr. Charles Bullard in a pond west of Winter Pond, Winchester, Mass., July 15, 1908. Type in Herbarium E. N. T. (Plate XIV, Figs. a-e.)

EXPLANATION OF PLATE XIV.

Figures a–e. *Bulbochæte Bullardi* nov. sp.
Figures f–i. *Oedogonium hystricinum* nov. sp.

a—Male filament showing strict habit, basal cell and five androsporangia. b—Imperfect oogonium with two dwarf males, antheridia and sperms. c—Immature oogonium. d—Mature oogonium and oospore. e—Five androsporangia. f. g. h—Female filaments showing mature oospores and dwarf males. i—Male filament with androspores. Camera lucida drawings.



E. N. Transeau and Hanford Tiffany

NOTES ON THE NEARCTIC NUSA (DIPTERA, ASILIDÆ).

W. L. McAtee.

During a study of the species of *Laphria* occurring north of Mexico, enough was learned also of the species of *Nusa* inhabiting that region to extend our knowledge of the group—information that has never been summarized. *Nusa* may be recognized as a genus, not on the principal character advanced in the original description,* closure of first posterior cell, which is sometimes true, sometimes not, but upon the grounds of habitus, and characteristic genitalia. Nearly all the species have well developed pruinose markings on thorax, including three pairs of lateral lunules and one to three longitudinal vittæ. The male forceps are short and one or both pairs of claspers are exposed beyond apex of forceps, seeming a continuation of them. The male hypopygium is thus quite distinct from the types exhibited by the nearctic genus to which *Nusa* is most closely allied, that is *Laphria*, in which the apex of the forceps itself is expanded and variously modified, and nearly or quite conceals the claspers. In some species of *Nusa* the femora are swollen and tibiæ curved; in others these characters are not pronounced.

Key to the Species.

a. Only apex of abdomen yellowish to reddish.
  b. Length over 20 mm.; genitalia as in Figure 1................. *cruenta* n. sp.
  bb. Length less than 20 mm.; genitalia as in Figure 2.......... *fulvicauda* Say.
aa. More of abdomen so colored.
  c. Sides of abdomen black, wings distinctly marked, genitalia as in Figure 3. .... *sicaria* n. sp.
  cc. Abdomen without black markings, wholly yellowish to reddish; genitalia as in Fig. 4.................................... *abdominalis* Brown.

Nusa cruenta new species.

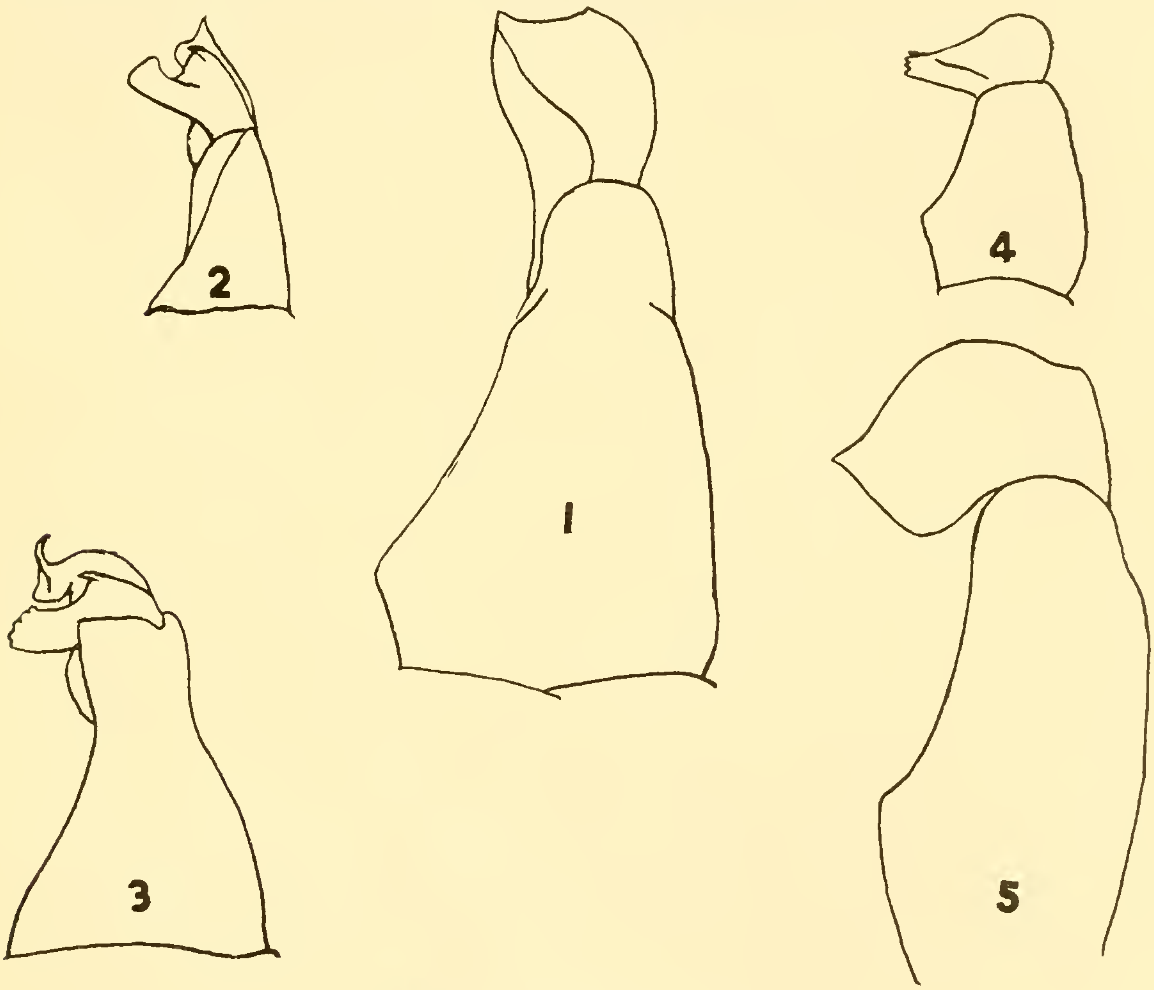
A black species with seventh abdominal segment and hypopygium reddish testaceous; exposed membranes of abdomen same color and halteres somewhat paler. Thorax apparently entirely without pruinose markings; though this may be due to methods of preparing this individual specimen. Bristles on facial prominence black, remaining pubescence of head, coxæ, and lower surfaces of legs, long, copious, grayish.

* Walker, Francis. Insecta Saundersiana or characters of undescribed insects in the collection of William Saunders, Esq., F. R. S., F. L. S., etc. Vol. I, Diptera, 1856, p. 105.

Pubescence of upper surface of legs, and of tarsi black. Upper surface of thorax with sparse short, pale hair; tuft of hair in front of halteres pale, in front of wings black; thoracic and scutellar bristles also black. Pubescence of abdomen chiefly pale on first three, mostly black on remaining segments, longer at sides; each of segments 2–6 with a strong bristle on each side. Wings fumose, pale toward base, first posterior cell open. Male forceps and claspers as shown in Figure 1. Length, 24 mm.

Type, a male from Florida (U. S. N. M.)

This specimen was figured in The Insect Book, L. O. Howard, 1901, Pl. XXIX, Fig. 15, as *Nusa fulvicauda*.



MALE GENITALIA OF NUSA

Fig. 1. Nusa cruenta n. sp. Forceps from side.

Fig. 2. Nusa fulvicauda Say. Forceps from side.

Fig. 3. Nusa sicaria n. sp. Forceps from side.

Fig. 4. Nusa abdominalis Brown. Forceps from side.

Fig. 5. Nusa n. sp. near rubida Williston. Forceps from side. This species, from Mexico, is not described but is figured to show an additional variation of the *Nusa* type of hypopygium.

Nusa fulvicauda Say.

Laphria fulvicauda Say, Thomas. American Entomology 1, 1824, p. 12, Pl. VI (Cote sans Dessein, Missouri River). The Complete Writings of Thomas Say on the Entomology of North America, 1, 1859, p. 12.

Laphria pyrrhacra Wiedemann, C. R. W. Auszer-europaische zweiflugelige Insekten 1, 1828, pp. 517–518. (Brazil, Savannah and Missouri).

A synonym at least so far as United States specimens are concerned.

Black with face, occiput, coxæ and pleuræ more or less silvery pruinose, and following pruinose markings on disk of thorax; a bluish gray median percurrent vitta, and two lateral irregular vittæ expanded externally at 3 points and connected with silvery pruinose patches (the lunules) along sutural areas. Mystax black, face with silvery pile and longer decumbent hair; beard, coxal and pleural hair grayish white. Short sparse hair of upper surface of thorax black; bristles of thorax and scutellum black. Pile of abdomen pale, longer at sides of segments, forming conspicuous tufts on segments 2–6. Segment 2 with two strong black bristles on each side, segments 3–5 with one. A spot involving part of segment 6, all of 7 and part of hypopygium, yellowish to reddish with concolorous hair. Hair of legs gray and black, bristles black; wings fumose, clearer within cells and toward base. First posterior cell closed in both wings of three specimens, in one wing of one specimen and open in both wings of nine specimens. Hypopygium black and red, forceps and claspers as in Figure 2. Length, 15–18 mm.

Specimens examined: Toronto, Ont., Oct. 7, 1887, Wm. Brodie, (U. S. N. M.); Linglestown, Pa., July 16, 1913, W. S. Fisher, (U. S. N. M.) Aug. 4, 1912; Champlain (Walton); Harrisburg, Pa., June 13, 1912, Champlain (Walton); Great Falls, Va., July 12, 19, 1916, J. N. Knull, (U. S. N. M.); Cabin John Bridge, Md., July 25, 1913, R. C. Shannon, (U. S. N. M.); Washington, D. C., Aug. 22, 1912, F. Knab, (U. S. N. M.); Wauseon, Ohio, (K. U.); N. C., Fla., (U. S. N. M.); Brownsville, Texas, June, F. H. Snow, (K. U.); Los Angeles Co., Calif., July, (U. S. N. M.), Locality correct?

A ♂ specimen labelled Col. [orado], Snow, (K. U.) has segments 3–7 involved in the abdominal spot; it is made the type of variety *lutea*, new variety. The Brownsville specimen approaches this form.

Nusa sicaria new species.

Ground color reddish brown, appearing lilac-brown where pruinose, with black markings as follows: basal 2 joints of antennæ, beak and region of its insertion, legs except basal two-thirds of tibiæ, 3 large patches on each side of thoracic disk, posterior part of scutellum and thorax beneath it, and more or less of sides of abdominal segments, being most extensive on 5 and 6. Face, except prominence, pleuræ, lateral vittæ, and lunules of thorax, densely white to silvery pruinose; coxæ, occiput below and median percurrent, thoracic vittæ gray pruinose. Short pile on thoracic vittæ black, as are also thoracic and scutellar bristles. Mystax of short, stubby black bristles, decumbent pile of face white; beard and most of hair of legs grayish; pleural hair and tufts a little tawny. Abdominal pile pale, short on middle segments, longer at sides especially toward the base. Two stout black bristles on each side of segment 2, one each on segments 3–5. Abdomen reddish brown, blackish at sides, especially on segments 4–6, segments 6–7 and hypopygium mostly yellowish red. Forceps and claspers as in Figure 3. Wings clear with distinct fuscous clouds at base, at apex of basal cells and at apex of discal cell, following to some extent the neighboring veins. In one specimen the anterior branch of third vein in each wing has a stump. First posterior cell closed before border of wing. Length 17–20 mm.

Type, a male from Nueces River, Zavalla Co., Texas, April 26, 1910, Hunter and Pratt, (U. S. N. M.).

Other specimens examined: San Diego, Texas, May 7, E. A. Schwarz, (U. S. N. M.); Los Borregos, Brownsville, Texas, June 5, 1904, H. S. Barber, (U. S. N. M.).

Nusa abdominalis Brown.

Nusa abdominalis Brown, Barnum. Two new species of Asilids from New Mexico. Kansas University Quarterly, 6, No. 2, April, 1897, p. 103. (Cuba, Bernalillo County, N. Mex.)

Ground color of head and thorax black; face and occiput densely covered with silvery gray pruinosity, rather copious decumbent pile of face, mystax and beard of same color. Thorax also almost entirely covered with pruinosity, in this case yellowish gray, leaving ground color exposed above in two narrow vittæ anteriorly and two broad, posteriorly arcuated and medianly interrupted transverse fasciæ on posterior part of thorax. Tufts of hair in front of halteres and short pile of pleuræ, coxæ, etc., silvery gray; bristles around edge of thoracic disk, and on scutellum tinged with yellowish. Abdomen honey yellow, with sparse short pale pile and stout pale bristles, 2–3 on each side of second and 1–2 on each side of following abdominal segments. Legs about same color as abdomen, femora black apically; front tibiæ black apically, other tibiæ chiefly and tarsi entirely black; hairs and bristles yellowish. Wings hyaline, slightly yellowish tinged; all posterior cells closed remote from margin. Hypopygium as in Fig. 4. Length 11–13 mm.

Specimens examined: Bill Williams Fork, Ariz., Aug., F. H. Snow. (Hine).

Two specimens, the general coloration of which is obscured by grease suffusion, differ from the foregoing by having the legs black (except base of tibiæ faintly reddish). They may be known as variety *atripes* new variety.

Specimens examined: Mesilla Park, New Mexico, on sand hills, July 12, 1897, Cockerell. (Type, U. S. N. M.); San Bernardino Ranch, Cochise Co., Ariz., 3,750 feet, August, F. H. Snow. (Hine).

Whether *N. similis* Brown (loc. cit.) is a distinct species is doubtful. The original specimens have not been available, hence a decision on this point is not possible. The chief character used for distinguishing the species, namely, number of bristles on sides of abdominal segments, is shown to be variable in *N. abdominalis*, and the variations may cover *N. similis*.

Date of Publication, February 27, 1919.

Scientific Results of the Katmai Expeditions of the National Geographic Society.

VIII. A STUDY OF TEMPERATURES IN THE VALLEY OF TEN THOUSAND SMOKES.

Jasper D. Sayre and Paul R. Hagelbarger.

The most serious failure of the expedition of 1917 was its inability to measure the temperatures of the volcanoes in the Valley of Ten Thousand Smokes. The Smokes were so much hotter than had been anticipated that the expedition found itself without the apparatus necessary for their measurement. An ordinary mercury thermometer, registering up to 350° C., was all that had been provided. The top of this was soon broken, but before this accident occurred, it had been discovered that many of the temperatures were beyond the range of this instrument, or at least so near the limit of its readings that it was not considered safe to immerse it in the hot vapors long enough to allow the mercury to expand fully for fear of bursting the tube.

One of the principal objectives of the Expedition of 1918, which was undertaken by the authors, was therefore the study of the temperatures of the vents in the Valley.

In this project, as well as in the chemical study of the volcanic gases, the expeditions were aided by the Geophysical Laboratory of the Carnegie Institution, which undertook to supply the necessary equipment. But on account of the war considerable difficulty was experienced in securing the requisite instruments. Potentiometers of the Leeds and Northrop type were not to be had. It was indeed by the narrowest margin that any pyrometers were obtained at all. Up to within twenty-four hours of the departure of the expedition we had not succeeded in obtaining any instruments whatever. But on the last day a pyrovolter from the Pyrolectric Instrument Company, of Trenton, New Jersey, and a pyrometer from the Hoskins Manufacturing Company, of Detroit, arrived.

Although such hasty tests as could be made amid the hurry of the last preparations for departure indicated that both instruments were in working order, it was not possible to gain

Photograph by C. F. Maynard

LOOKING SOUTHWEST FROM STATION IX ACROSS THE VALLEY.

Showing the location of Fumaroles 29, 30, 31, 32, 33, 34, 35, 36, 37, 45.

that acquaintance with their behavior nor to test the accuracy of their readings, which everyone will recognize as highly desirable preliminaries to the use of any instruments.

But notwithstanding these handicaps, the instruments did good service in the field, giving identical and apparently trustworthy readings at all times. At the beginning of the work their readings were compared in the vapor of Fumarole No. 1, which was convenient to our camp; and again at the close of the season, when checked at the same vent, they gave the same readings as at the beginning, thus allowing us to repose confidence in their readings throughout.

Two months later, when they were unpacked after being returned to Columbus, it was observed that, while the Hoskins instrument was apparently still in good order, the battery (dry cell) of the pyrovolter had completely gone bad. They were then repacked and shipped to the Geophysical Laboratory where they were recalibrated by E. D. Williamson, who reported as follows:

"Temperature,	448,	444,	441,	433,	351,	348,	254.
Reading (Hoskins Instrument),	458,	453,	450,	443,	359,	355,	259.
Reading (Pyrovolter),	441,	442,	441,	438,	348,	343,	255.

"The readings in the first row were taken with Pt. Rh. thermoelement. You will notice that the Hoskins combination reads consistently about 2% too high, while the other is less consistent, but does not involve errors greater than the expected accuracy permits. We found that the battery in the pyrovolter was completely used up, but hope that this did not affect any of your readings.

"The two thermometers were calibrated at the boiling point of water, where each read 0.3° too low."

Following this report the readings observed in the vents have been corrected to accord with the recalibration. Because of the great variations encountered from place to place in a column of escaping gas it was not considered advisable to attempt to read the instruments closer than the nearest 5°. Where the correction is applied the resultant temperatures are usually expressed by an intermediate figure. They are recorded as they came out after correction, but such temperatures, as for example 299° C., would be best considered as 300° C., for no implication that the errors are less than 3° either way is intended.

The method of procedure in the field was, starting out in the morning with packs containing thermometers, one or both pyrometers, 5 x 7 camera, Kodaks, spade and other necessary

Photograph by C. F. Maynard

LOOKING SOUTH ACROSS THE HEAD OF THE VALLEY FROM BAKED MOUNTAIN.

Showing the location of Fumaroles 5, 8, 9, 14, 15, 16, 17, 18, 19, 20, 21.

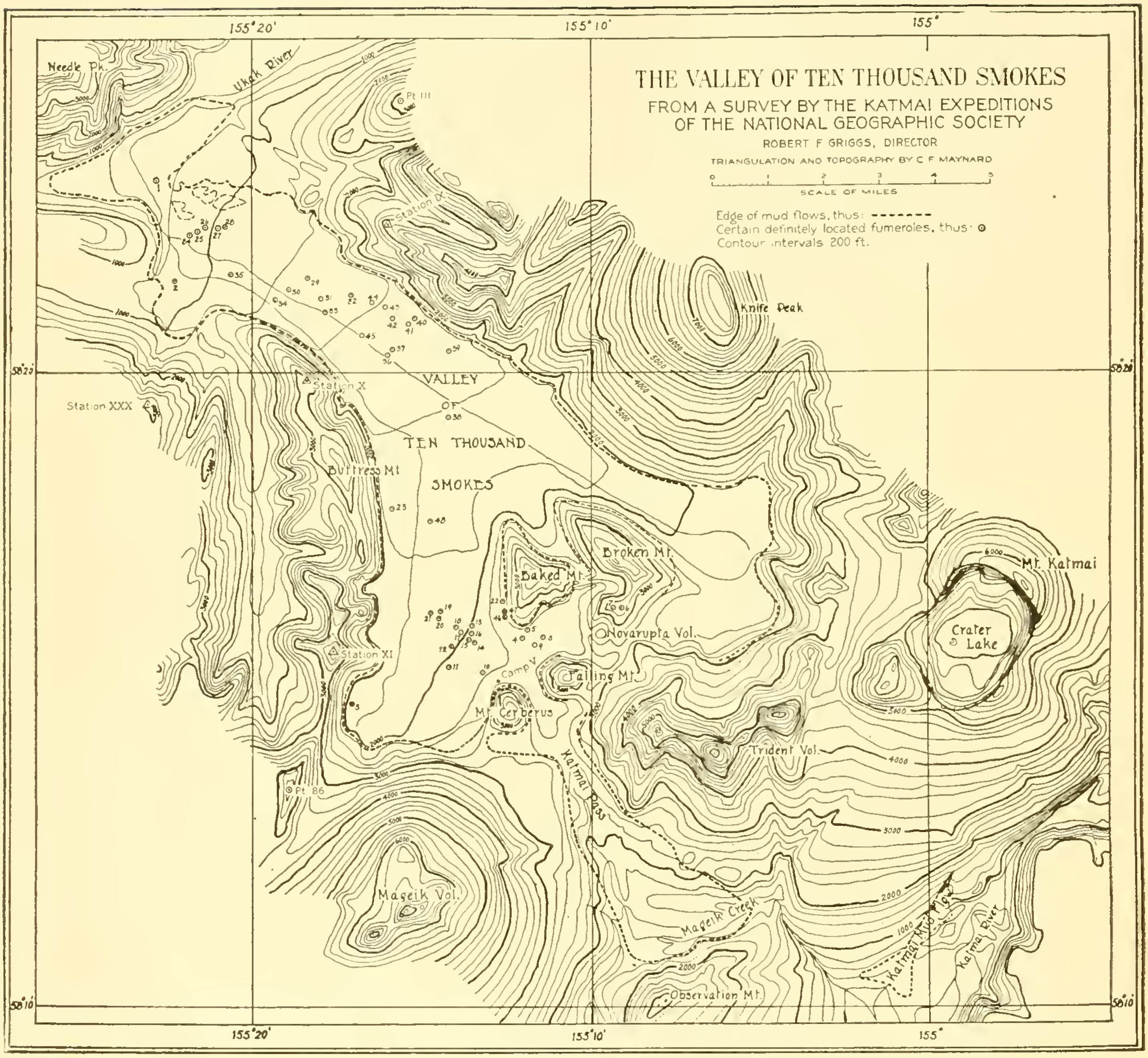
equipment, to proceed to examine all vents in the area selected for study. It was our custom to proceed rapidly, giving the vents a preliminary examination with a thermometer which read to 210° C. It could be thus readily determined whether a given vent was merely at the boiling point—which of course is the temperature of the vast majority of the orifices—or whether it was higher.

When this preliminary examination showed a temperature above 100° C., and the fumarole was so situated that it was accessible for measurement by our instruments, the packs were opened, a record of the temperature secured by the pyrometers, and the position of the vent recorded by means of magnetic readings on a Brunton compass, from fixed triangulation stations on the mountains around the Valley.

But many of the largest and most important volcanoes of the Valley were so situated as to make it altogether impracticable to measure their temperatures with our instruments. Thus, although Novarupta has every appearance of being the climax of the activity of the Valley, we were unable to reach any vent in its vicinity whose gases were more than 100° C.

In order to judge rightly the degree to which the results obtained may truly represent the activity of the Valley, the reader should, therefore, understand some of the limitations of the instruments with which they were secured.

In the first place, our thermocouples were insulated with unglazed porcelain tubes for about two feet at the end, and above that with asbestos. Now, if the wires touched or were short circuited at any place other than the twisted couple, the temperature recorded would be that of the junction nearest to the registering instrument. Therefore, the asbestos insulation which protected the wire was all right as long as the instruments were dry, but if the steam condensed and saturated this covering or the two wires touched, the resulting temperature would be that of the condensed steam, or about 100° C. This occurred frequently because the steam would condense where it came in contact with the cold air at the side of the hole. We overcame this by bending the wires so that they did not touch each other while in the steam. As almost every fumarole necessitated a different bending of the wires, the asbestos insulation and porcelain tubes were subjected to considerable wear and tear.


THE VALLEY OF TEN THOUSAND SMOKES
FROM A SURVEY BY THE KATMAI EXPEDITIONS
OF THE NATIONAL GEOGRAPHIC SOCIETY
ROBERT F GRIGGS, DIRECTOR
TRIANGULATION AND TOPOGRAPHY BY C F MAYNARD
SCALE OF MILES
Edge of mud flows, thus:
Certain definitely located fumeroles, thus:
Contour intervals 200 ft.
155°20'
155°10'
155°
58°20'
58°10'
Needle Pk.
Ukak River
Pt 111
Station IX
Knife Peak
Station X
Station XXX
VALLEY
OF
TEN THOUSAND
SMOKES
Buttress Mt
Broken Mt.
Baked Mt.
Novarupta Vol.
Station XI
Camp V
Falling Mt.
Mt. Cerberus
Mt. Katmai
Crater Lake
Trident Vol.
Katmai Pass
Pt 86
Mageik Vol.
Mageik Creek
Katmai Mud Flow
Katmai River
Observation Mt.

The same thing was apt to happen if the two wires were allowed to rest on the wet ground, as the steam usually kept the ground around the fumaroles damp. We therefore supported the wires on some object, such as a spade or a pole. The porcelain tubes, too, would sometimes collect the condensed steam and short circuit the instrument. As the two wires went through perforations in the same tube, the only remedy for this was to allow them to dry out again if they became saturated with water. This was usually accomplished by allowing the thermocouple to remain in some hot fumarole for a considerable length of time. As one had to thrust the wires from the cold air into the hot steam, more or less condensation always occurred. If the fumarole was above 200° C. the condensation would not be very great and the tubes would quickly dry out, but if it was just above the boiling point, so much water would condense that we would get a temperature of only 100° C. As a result, we obtained very few temperatures just above the boiling point, because we did not wait long enough for the tubes to dry out or because the temperature was not high enough to dry them out. Out of the 48 fumaroles, or areas of fumaroles, we studied, only six were found which registered between 100° C. and 190° C.

Many of the fumaroles of the Valley were inaccessible to us with the instruments which we had. The thermocouple of the pyrovolter, which was six feet long with 50 feet of lead wire, was made of such small wire that it would not support its own weight, so we had to attach it to a long pole. This complicated matters considerably, for if we used wire to fasten it on, the insulation would quickly burn through in hot fumaroles and short circuit the wires, and if we used string, rope or something of that nature, it was very soon burned off. Besides, the pole served as a collector of steam and, although the wires did not touch, they were short circuited by the steam, especially at the point of contact of the cool air and the hot gases. The only practical and satisfactory way in which we could use this six foot thermocouple was for lone fissures or cracks not surrounded by an area of steam, where the temperature at the surface or six inches down was required. It was in these places that we used it to check up the readings of the pyrometer.

The thermocouple of the Hoskins pyrometer was 10 feet long with 30 feet of lead wire. At the end used in the hot gases, the wires were simply twisted together and welded in a high temperature furnace. The other end, from which the lead wires ran to the recording instrument, was covered with a wooden handle. This end, the cold junction, was connected with a small open coil of fine insulated wire inside the handle and had to be kept at the air temperature the same as the recording instrument, as well as dry and clean. This limited the use of the thermocouple to a length of eight feet in a hole. In many cases the steam around the vents was so thick as to prohibit its use at all. We partly overcame this in some cases by wrapping the cold junction in a towel to keep the steam from condensing in the coil. While this limitation made no difference in narrow throated fumaroles, it was a serious handicap in dealing with large crater-like vents where one could see for 50 or 60 feet down the hot throat. In one of the "Twins," for example, where the temperature at the surface was 309° C. we wondered what the temperature would be 60 feet down the hole.

The recording instruments, moreover, had to be kept dry and at the air temperature. The ground for a considerable distance around any area of activity was so hot that correct results could be obtained only by keeping the recording instrument off the ground by setting it on a packsack, sample box or old coat.

Besides these difficulties, there was the personal danger of getting too close to the hot steam, or of breaking through the thin crust over a line of fissures. In many cases we were not able to get near enough to use our instruments at all. If there was a strong and constant wind, we could work quite close to the orifice on the windward side without much danger, but we had to be very careful not to get close enough to produce a back draft or undertow against our bodies. This happened several times in low temperature "steamers." In such cases we had to throw ourselves away very quickly to avoid serious injury, for if one should get into a flare-back from one of those which recorded 300° C., he would be in great danger of terrible injury.

While some of the vents are mild mannered "steamers" emitting principally water vapor, the vapor from others appears altogether dry and consists largely of other gases which are generally disagreeable and sometimes, as for example when heavily charged with hydrofluoric acid,* dangerous if inhaled.

*Analyses of the gases given off from the vents have been begun by Dr. E. S. Shepherd of the Geophysical Laboratory.

Because of the prevalence of strong winds these gases did not interfere with the work as much as might have been expected, but they are an ever present menace and there are considerable areas into which no explorer has yet dared to penetrate for fear of being overwhelmed by the fumes from the thickly placed vents.

CLASSIFICATION OF FUMAROLES.

Since the fumaroles of the Valley manifest an almost endless variety of form, size and character, it is difficult to find any satisfactory basis for their classification. Nevertheless it will

Photograph by Jasper D. Sayre

THE THROAT OF FUMAROLE 5 WITH THE THERMOCOUPLE HUNG DOWN SIX FEET INTO THE HOLE.

The temperature was 231° C. at this place. The steam did not condense until some distance from the throat. This fumarole is shown from a distance on page 252.

conduce to clearness of thinking to separate them roughly into the following groups. But it must be recognized that there are no distinct lines to be drawn between the different categories, for they intergrade in every way.

1. *Chimneys:* Isolated single holes on the general level of the surrounding Valley floor, with chimney-like throats. There was no surface indication of a lengthy fissure nor of ejecta thrown out around them. The temperature was usually high, (Example No. 5, page 265). These chimney-like fumaroles are

commonly scattered over the Valley. We worked at ten different fumaroles of this type. In this class of fumarole the highest temperature was usually at the surface of the ground, rather than down six or eight feet in the throat. Because of their isolation they were easier to work with than any of the other kinds.

2. *Surface fissures:* Continuous long lines of irregular cracks and crevices, evidently formed in the roofs of lengthy fissures. The surface is baked hard and is conspicuous with its bright deposits and incrustations. The temperature

Photograph by Jasper D. Sayre

AREA 29.

By repeated attempts at different fissures in this line of action, we obtained a maximum temperature of 329° C. The surface of the ground was icrhly colored with incrustations.

was high and the clouds of steam of great volume. These surface fissures are among the most conspicuous and abundant vents in the Valley. They were often 200 yards in length. Occasionally small explosion craters have been formed along the fissures. These have rims of ejecta four or five feet in height and ten feet or so in diameter. The steam was issuing from cracks in their throats, similar to those occurring in the surface of the fissure, (Example, No. 29, page 272).

Surface fissures are the most abundant type of vents in the Valley. Over half the areas which we visited were of this type. Some of them were easily accessible, but, in order to work others, it was necessary for one man to hold the recording instrument while the other held the thermocouple and moved it from crack to crack. In this way we recorded a number of different temperatures from each area until we found the maximum.

3. *Large steamers:* Large irregular holes resulting from the cave-in of the roofs of wide fissures. They emit a large column of steam under pressure and are very conspicuous and most common near the high mud mark along the edge

Photograph by D. B. Church

A PORTION OF THE EDGE OF THE CRATER OF No. 21.

It was impossible to get a satisfcatory photograph of the interior, or to reach the bottom, but a small crack just within the rim gave a temperature of 196° C.

of the Valley. The vent is always large and perhaps much hotter than the temperature which we were able to secure at the edge of the hole would indicate. (Example, No. 22, page 273).

4. *Craters:* Large crater-like orifices, evidently of explosive origin and occurring generally in the floor of the Valley. Many cracks and fissures radiate out from them. They are surrounded by a ring of ejecta rising 15 or 20 feet above the Valley floor and are very conspicuous because of the large amount of steam given off. In no case was it possible to approach the orifice from which the steam emerged to take the tem-

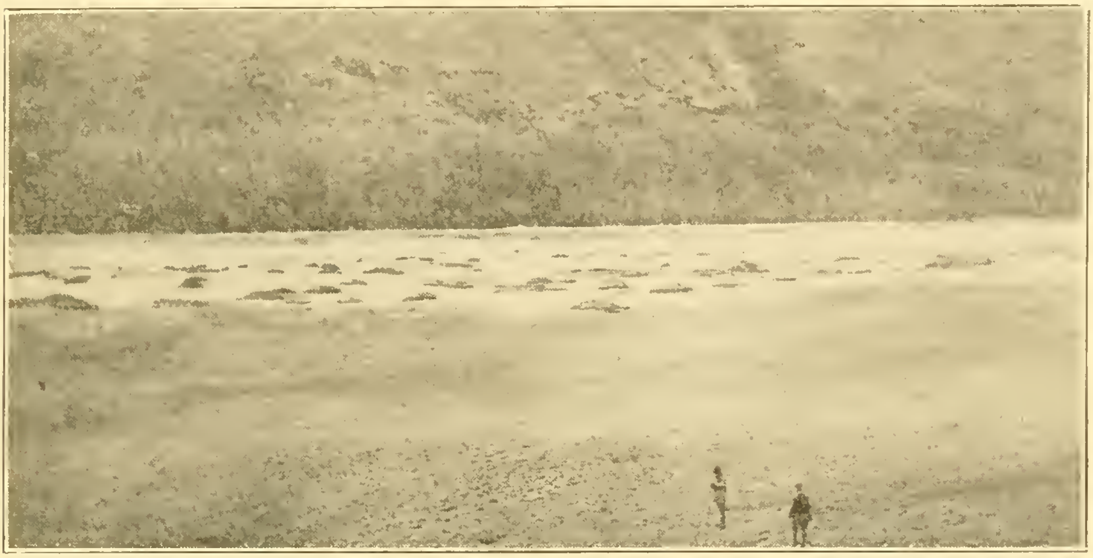
perature, but in one of them (No. 21), we found a temperature of 196° C. in a lateral fissure just inside the rim.

5. *Cracked areas:* Areas with a hard baked surface, much cracked and honey-combed with small fissures. Definite individual vents are rare. The surface cracks are filled with steam coming from below, under considerable pressure. The gases in the steam form a thick deposit on the surface of the mud. They are abundant on the slopes east of Falling Mountain. The emanations from these areas are so copious and they appear so hot and so charged with noxious gases that no one has yet had the temerity to undertake their exploration.

6. *Mud blanketed areas:* Although the general surface of the original mud flow that forms the floor of the Valley has become hard and firm, there are many areas covered with soft, sticky blue mud, which is kept hot by the steam which issues through it in considerable quantity. The activity of these mud blanketed areas takes on one of two forms. Usually it gives rise to myriads of small steam jets best described as *mud hissers*, which come out from indefinite cracks. Although the mud is always blue, the surface is generally covered with a chestnut brown crust which will sometimes support a man's weight. The minute orifices, by which the steam punctures the crust, probably do not constitute permanent vents but presumably shift about rather rapidly. The temperature of the steam and of the surrounding mud was close to that of boiling water. The conspicuousness of these areas varied greatly with the humidity of the air. Although these areas are very common in the center of the Valley, we located only one of them with compass bearings. This one was No. 38, which is the most northerly of these areas in the Valley.

7. *Mud volcanoes:* In some of the mud covered areas the activity produces a more or less violent ebullition, forming mud pots and mud volcanoes. The consistency of the boiling mud varies from a soupy liquid to a viscous mush. The temperature of all was 100° C. We found only two areas of mud volcanoes in the Valley. The first, (No. 48), is in the center of the Valley and is made up of some 15 or 16 crater-like pots. The other area, (No. 44), is located near the northern end of the Valley and containes a line of six very active boiling pots of mud.

8. "*Pimples:*" At the lower (north) end of the Valley where sand storms are frequent, many of the smaller vents have built up conspicuous mounds around their orifices from the wind blown sand, which sticks to their moist surface and becomes a permanent addition to the pile. These mounds, see cut below, vary from six inches to two feet in height. Their temperatures did not exceed 100° C. We found them southwest of No. 24 and north of No. 1 in considerable numbers.



Photograph by J. W. Shipley

"PIMPLES" ON THE NORTH END OF THE MUD FLOW.

Near the north end of the mud flow many stratified piles are formed by wind blown ash which is caught and held by the steam from small fumaroles, giving the appearance of pimples breaking out on its surface.

LIST OF FUMAROLES.

In the list of fumaroles the maximum temperature (corrected) recorded follows the number. Next are given compass bearings on triangulation stations on the mountains around the Valley, whereby fumaroles may be located again with certainty. No attempt has been made to correct for magnetic variation, because the compass is subject to local irregularities which would made correction difficult but do not affect the value of the bearings for relocating the fumaroles, since the irregularities will probably remain sensibly constant for a given station.

The photograph numbers given after the descriptions are the serial numbers of the photographs secured by the expeditions. Complete sets of the prints are on file in the office of the National

Geographic Society in Washington and in that of the Director of the expeditions at Columbus, Ohio. The negatives, for the present, are filed in the Columbus office.

No. 1. Temperature 220° C. (Corrected). 111, N 49 E (Mag.) XXX, S 8 E. IX, N 79 E.

Approaching the Valley from the northern extremity of the Great Mud Flow, the first conspicuous fumarole was encountered about 200 yards north of the narrow neck at the easterly bend of the mud flow. The hole was about 18 inches in diameter, on a fissure perhaps 100 feet long, running east and west. The surface of the fissure was light

Photograph by Jasper D. Sayre

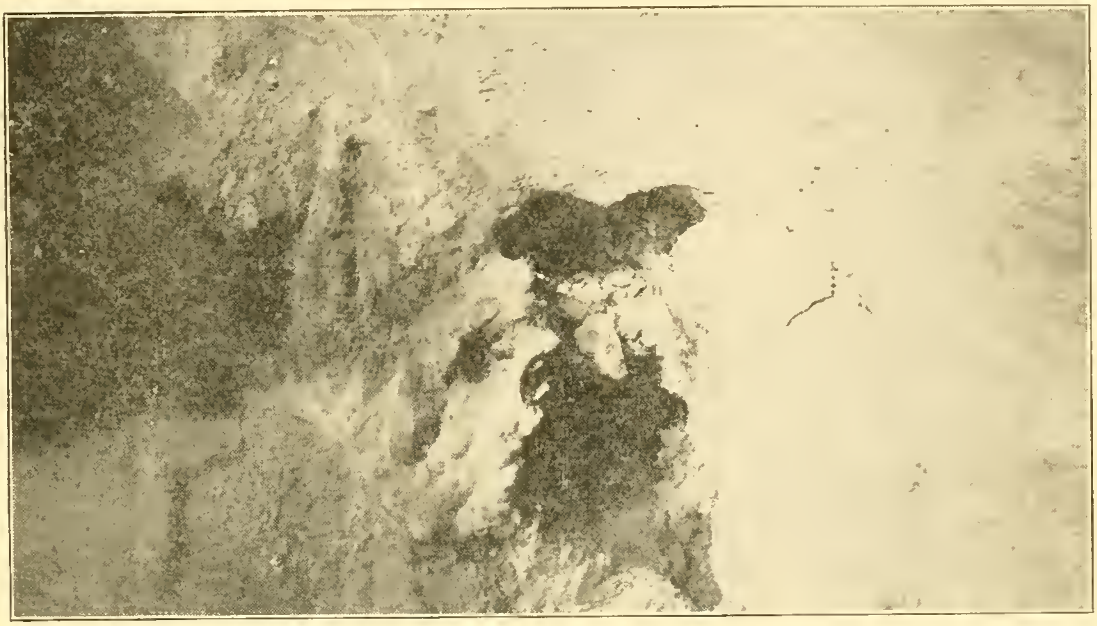
THE STEAM FROM FUMAROLE 3.

Fumarole 3 is located near the high mud mark under Station XI. The areas around it are very much broken up, and highly colored. This photograph shows the steaming fissure and its surrounding area.

colored, while the throat had a hard brown incrustation. The gases were emitted with considerable pressure, and were not condensed until several feet from the vent. This region was visited July 13th, and again on August 1st. No change could be observed; 220° C. was registered both at the surface and five feet down in the throat. Photograph 3769.

No. 2. T. 205° C. Needle Peak, N 51 W. 112, N 16 E. IX, N 76 E.

This was a small dry hole in the mud flow, where it had turned around the north end of Buttress Mountain and dammed Windy Lake. It was about 100 yards from the River Lethe Canyon, and just north of some sand knolls. The ground was strewn with partly charred logs and was very dry and sandy. The hole was about one foot in diameter and three feet deep, with a diagonal crevice two inches in diameter at the bottom from which the gases were given forth with considerable force, emitting a hissing sound. Wood would char and matches ignite when left in the vent. No deposits incrusted the throat, and the gases appeared entirely free from water vapor, although there was a melting snowdrift within 50 yards of the vent. Because of this absence of steam, Fumarole No. 2 would be passed unnoticed at a distance of 100 yards. On July 14th, at the surface of the ground there was no definite temperature, it fluctuated with the wind, etc, but four feet down the temperature was 182° C., six feet down, 205° C. On July 20th, four feet down, the pyrometer registered 182° C. Photographs 4133, 4544, 4545.



Photograph by Jasper D. Sayre

THE THROAT OF FUMAROLE 3.

This was the hole from which we obtained the temperature. There were several small and insignificant steaming cracks which registered only 100° C., not shown in this picture, and the mud was steaming in many places. T. 186° C.

No. 3. T. 186° C. 86, S 7 W. Baked Mountain, N 27 E. Mt. Cerberus, N 66 E.

This was a conspicuous steamer, with very bright red deposits, visible from any place in the upper end of the Valley. It was high up, near the high mud mark south of Station XI, about one mile north of Mageik Glacier. The surroundings were much shattered and the vent very actively steaming. The opening leads eastward and was about two feet across, evidently being the mouth of a long narrow fissure. We attempted to tap this underground fissure about ten feet from the mouth, but although the incrusted mud was only three or four feet in thickness, yet the spade would not penetrate it, as the heat had baked it as hard as rock. The opening was irregular. By placing the thermocouple from the pyrometer down in the fissure as far as we could without getting the cold junction in contact with steam, only 146° C. was recorded. At the surface, however, it was 186° C. Photographs 4521, 4522, 3697, 3698 (See cut above), 3699, 3700 (See page 262).

Photograph by Lucius G. Folsom

A GENERAL VIEW OF FUMAROLE 4 AS IT APPEARED IN 1917.
The shape of the throat had changed somewhat when visited again in 1918.

No. 4. T. 235° C. S6, S 31 W. Mt. Cerberus, S 15 W.

This was a brilliantly colored hole between Katmai Pass and Broken Mountain. The hole was on the north side of a gully, about four feet up, and was nearly two feet across, but became very small three or four feet in. The deposits were yellow and red, and very attractive. The entire gully was much visited in 1917 by Dr. Shipley. As at Fumarole 3, we attempted to tap the fissure which ran almost parallel with the surface, but were unable to break through the hard incrustation with which the tube was surrounded. The temperature at the mouth was 235° C, and about six feet down, 215° C. Photographs 3008 (See page 264), 3705.

Photograph by Jasper D. Sayre

THE THROAT OF FUMAROLE 6.

This irregular throat prevented us from getting a temperature very far below the surface, because it was impossible to bend the end of the thermocouple which was insulated with porcelain tubes. This picture shows the thermocouple in the position where it registered 260° C. Some indications of the bright incrustations are also shown.

No. 5. T. 309° C. Baked Mountain, N 19 W. XI, S 60 W. Mt. Cerberus, S 14 E.

This was a round hole about a foot in diameter in the flat surface of the mud flow north of Fumarole 4, and could be recognized by the fact that the steam did not condense until ten feet above the ground. The incrustations were light yellow and dark brown, and very hard. The temperature at the surface was 309° C; six feet down, only 231° C. Photographs 3706 (See page 257), 3707, 3708.

No. 6. T. 264° C. Knife Peak, N 3 W. IX N 61 W.

This acid fumarole lay in the gulch that is prominent as a notch on the upper edge of the crater rim of Novarupta. It is about 200 yards east of the edge of the crater. The deposits were a bright yellow and the fumes very acid, of powdery white appearance, with little steam. A single breath of these fumes made one cough and run for pure air. The opening was small, irregular and cracked, but the volume of gases emitted was great. The temperature at the surface was 260° C, 1½ feet down, 264° C. Photographs 3716, 3717.

No. 7. T. 166° C. West of No. 6, 200 yards.

This fumarole was 200 yards N. W. of No. 6, on top of the east bank of the north-south gulch cutting across the mountain east of the crater of Novarupta. The temperature was 166° C. Some very interesting colloidal red and orange deposits were found in the throat. It was a long fissure roofed over most of the way with deposits, but steaming in several places. The best deposits were exposed by the spade about one foot down.

Photograph by Jasper D. Sayre

TAKING THE SURFACE TEMPERATURE OF FUMAROLE 10.

As in the case of most of the hot ones, the steam did not condense until some distance from the orifice. With the thermocouple in the position shown, the temperature was 240° C. An idea of the appearance of this vent from a distance may be gained from the Smokes in the background.

No. 8. T. 294° C. Mt. Cerberus, due S. Baked Mountain, N 18 W. XI, S 65 W.

This was on the Valley floor between Falling Mountain and Broken Mountain, about 500 yards beyond a big steamer under Falling Mountain, in which no temperature above 100° C. could be found although Sayre went down twenty feet into its throat supported by a rope. No. 8 was a round hole, about two feet in diameter, in hard baked sand on the bank of a gully. The deposits for 25 feet around were white and very hard, with purplish brown incrustations in the throats of the many cracks and crevices from which the hot gases were issuing. Surface temperature 294° C.

No. 9. T. 274° C. 500 yards southwest of No. 8.

This steamer was similar to No. 5, with no conspicuous deposits, and was 274° C. at the surface, while the highest we could find three feet down was 240° C.

No. 10. T. 240° C. XI, S 71 W. Baked Mountain, N 12 E.

This fumarole was 800 yards straight down the Valley from Camp V. The gully starting at Camp V would lead almost to it. We could tell that it was a hot one, because the steam came out with force, and did not condense until it was a foot or more away from the hole. The temperature at the surface was 240° C. Photograph 3720 (See page 266).

To the west of it was an area of steamers which looked hot but did not register over 100° C.

No. 11. T. 196° C. Mt. Cerberus, S 60 E. IX, S 81 W.

This vent was toward Fissure Lake from No. 10, and was about the last one of the line which cuts across the Valley about one-fourth of a mile from the base of Mt. Cerberus. The deposits were brilliant red and orange. The opening was large and the volume of gas great. The temperature at the surface was 196° C., three feet down it was 171° C. and six feet down, 191° C. Photographs 4536 (See page 268), 4537, 4538.

No. 12. T. 299° C. Baked Mountain, N 30 E. Mt. Cerberus, S 60 E. 86, S 30 W.

This area lay about 300 yards northwest of No. 11. It was a mass of small fissures with white and brown incrustations. The temperatures recorded were: 171° C., 299° C., 289° C., 250° C., 240° C., 254° C., 230° C., 171° C. The cracks are irregular, with but little steam, and it was impossible to force the thermocouple more than six or eight inches below the surface. Photographs 3721, 4539 (See page 269).

No. 13. T. 181° C. XI, S 55 W. Mt. Cerberus, S 50 E. Baked Mountain, N 25 E.

This was a lone fumarole without much steam, and lay north of No. 12. The temperature, both at the surface and two feet down was the same, 181° C. Photograph 3722.

No. 14. T. 406° C. XI, S 67 W. Mt. Cerberus, S 52 E.

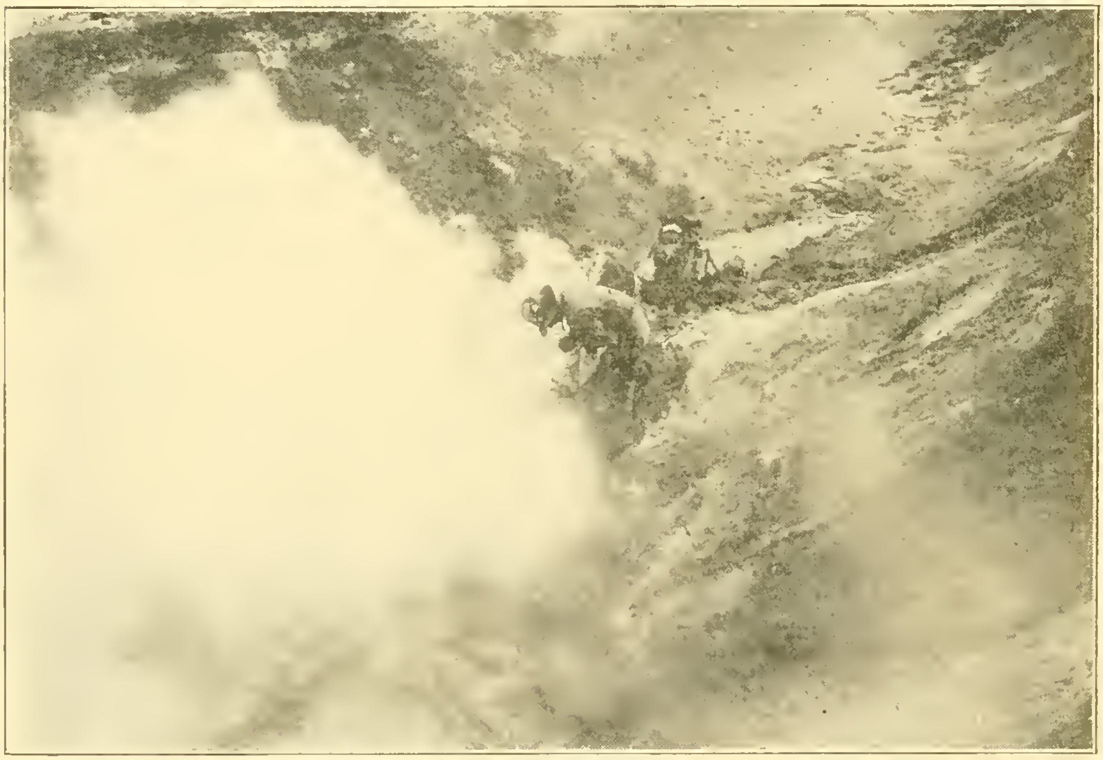
This was a long row of small craters, extending about 500 yards in a line between Katmai Pass and Station IX. The fumes from these holes were very acid, similar to those of No. 6 on Baked Mountain. The craters were conical in shape. The fumes came not from the bottoms of them, but from very small cracks in the sides or on the rim. We worked here for several hours and recorded the following temperatures from different cracks: 299° C., 323° C., 367° C., 272° C., 397° C., 392° C., 406° C., 196° C., 196° C., 323° C., 196° C., 196° C. The deposits were light colored and brown. Photographs 3722 (See page 271), 3723, 3724, 3725, 4540.

No. 15. T. 216° C. 500 feet west of No. 14.

This fumarole was on the same general line of craters as No. 14. The appearance also was much the same.

No. 16. T. 147° C. 200 feet north of No. 15.

This one was on the same general line of activity as Nos. 14 and 15, but it was a steamer. The gases were very wet, and the temperature was only 147° C. The bright orange and red deposits were conspicuous.



Photograph by Paul R. Hagelbarger

FUMAROLE 11.

Temperature 196° C. at the surface; 171° C. three feet down; 191° C. six feet down.

No. 17. T. 196° C. 100 feet west of No. 16.

This fumarole was on the same line of activity as Nos. 14, 15 and 16. It was also a steamer, similar to No. 16. The instrument recorded only 196° C. at the surface of the ground.

No. 18. T. 264° C. 150 feet northwest of No. 17.

This fumarole was on the same lines as Nos. 14, 15, 16 and 17. It was a small theater of hot small holes, with characteristic brown baked surface crust. We recorded two temperatures from it; one 264° C. and the other 250° C. The vents were merely small irregular cracks, neither depressed nor elevated above the general level of the Valley floor.

No. 19. T. 304° C. XI, S 50 W. Mt. Cerberus, S 55 E. Baked Mountain, N 48 E.

This was a big hole in the level Valley floor which gives forth steam and gases. The steam did not condense until some distance above the opening. There were no conspicuous deposits around the throat of the fumarole. It was a gray ash color similar to the surrounding Valley floor. Several feet down in the throat one could see the ordinary tuff of the mud flow. We obtained a temperature of 304° C. at the surface. Photograph 3726.

Photograph by Paul R. Hagelbarger

AREA 12.

This cracked and broken area, with white and brown incrustations, showed many different temperatures in the numerous crevices; maximum 299° C.

No. 20. T. 269° C. 75 yards south of No. 19.

Like the preceding, this fumarole was an irregular opening in the mud flow, with no conspicuous deposits, but surrounded by the common ash of the Valley floor. The temperature at the mouth was 245° C, but four feet down it was 269° C. Photographs 3727, 3728.

No. 21. T. 196° C. Mt. Cerberus, S 60 E. XI, S 48 W. Baked Mountain, N 48 E.

This large crater near the River Lethe was very brilliant and steaming copiously. We were unable to secure the temperature of the crater itself, but took the temperature of a small fissure in its rim. This registered 196° C. at the surface. The crater had a striking, dark red and black coating in its throat, and was a spectacle whenever the steam cleared from its rim. This rim was nearly 100 feet across and elevated 20 feet above the Valley floor. The funnel was 50 feet to its narrow throat. The gases tested were being emitted from lateral cracks in the rim, which were only a couple of inches wide. Photographs 2316A (See page 259), 3729, 3730, 4542.

No. 22. T. 343° C. XI, S 54 W. Mt. Cerberus, S 25 E. Baked Mountain, N 26 E.

This was a conspicuous steamer near the high mud mark on the west side of Baked Mountain, north of the "Twins," (No. 46 and No. 47). The hole was about eight feet in diameter, and the opening within so wide that one could see plainly through the transparent superheated vapors for 50 feet or more into the cavern, which extended diagonally toward the head of the Valley.

Although a few wisps of steam begin to condense around the mouth, the main column did not condense until it had reached a distance of 20 feet from the hole. On account of its size we were not able to work satisfactorily with this fumarole, but had to be content with hanging the thermocouple over the windward side of the hole, where we found a temperature of 343° C. Photograph 4543 (See page 273).

No. 23. T. 352° C. Mt. Cerberus, S 53 E. Baked Mountain, S 88 E. XI, N 24 W.

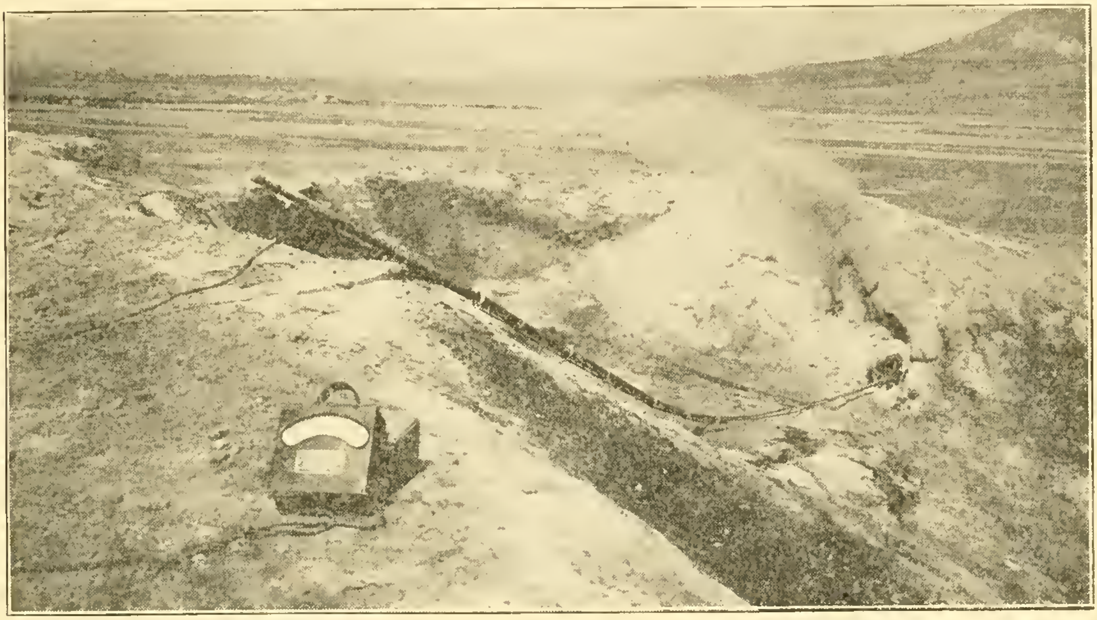
This steamer was located on the side of Buttress Mountain, near the bend in the range. It was an irregular opening with cracks radiating in every direction. We attempted to find the hottest place by sticking the thermocouple down about three feet in these different vents. We recorded temperatures in this manner of 196° C., 220° C., 245° C., and finally in one crack 294° C. This gradual rise in temperature excited our curiosity and we tried to find even higher ones. We finally recorded 352° C. as the highest temperature. This was found by holding the thermocouple suspended in the mouth of the fumarole. We repeated our observation and found that as soon as we moved the thermocouple from this certain spot it cooled off. Any other place down in the hole showed a much lower temperature. Three feet down, directly beneath the hot spot, the temperature was only 245° C. We repeated this work because we had expected to find higher temperatures down farther in the fumaroles. The deposits were heavy, bright red, orange and yellow.

No. 24. T. 230° C. IX, N 68 E. 111, N. 38 E. Needle Peak, N 59 W.

This fumarole had two openings, about eight inches in diameter and two feet apart. Both were 230° C. It was located in the canyon cut into the mud flow by "Chocolate Harry," the stream from under Knife Peak, near its junction with the River Lethe and Buttress Creek. The vapors were largely invisible gases rather than steam. In fact, we located it more by the noise it made than by its steam. The throats were baked hard, but the surrounding ash was soft, without conspicuous deposits. Photographs 4138, 4139.

No. 25. T. 274° C. X, S 59 E. IX, N 67 E. Needle Peak, N 64 E.

This was on the line of sand fissures that extends across the north end of the Valley from Pasture Peak to Station IX. It may be taken as typical of many similar fumaroles which are gradually increasing in size because wind-blown sand continually lodges around their throats. At first caught by the moisture of the steam, this is later cemented together by the emanations from the fumarole, forming showy layers of many hues. The insides of the throats are hard baked yellow. Round about were spots covered with a thin green layer of algæ (?). Photograph 3739.



Photograph by Jasper D. Sayre

ONE OF THE ORIFICES IN THE LINE CALLED, COLLECTIVELY, "AREA 14."

The temperature in the throat of this particular hole was 299° C. Another nearby registered 406° C.

No. 26. T. 196° C. 500 yards N 68 E from No. 25.

Similar to No. 25 in appearance and construction, being built up of wind blown ash, caught by the steam. Its hard baked throat was quite alone and not surrounded by any smaller cracks or crevices. The temperature was 196° C. Photographs 2141, 4140.

No. 27. T. 100° C. 50 yards East of No. 26.

Although similar to Nos. 25 and 26 in appearance and apparently as hot, this fumarole was much cooler and gave off much more steam than either one of the foregoing. It was not until we unpacked our pyrometer that we found that its temperature was only 100° C., otherwise we would not have stopped here. There was no conspicuous color in the throat, but the steam bathed ash was covered with a greenish crust. Collections of this ash are being cultured for algæ and moss protonema.

No. 28. T. 216° C. X, S 55 E. IX, N 67 E.

This was a long line of steamers, one hole of which showed a temperature of 216° C. Others registered 196° C. and 161° C. The main vents were 100 feet apart, closely similar in appearance. They were surrounded by numerous steaming cracks which stood at 100° C.

No. 29. T. 329° C. IX, N. 24 E. Baked Mountain, S 60 E. 111 N 0.

This was a long line of acid fumaroles. After many trials, we secured the highest temperature, 329° C. They were richly colored small holes. The whole line was slightly raised above the general level of the Valley floor. We began at one end of the line and after recording several crevices at 100° C., found higher temperatures as we approached the middle of the line, finally reaching the maximum of 329° C. Some of the other crevices recorded 313° C., 294° C., 259° C. Toward the other end of the line the temperature fell again to the boiling point. Photographs 3740, 4141.

No. 30. T. 304° C. 111, N 9 E. Baked Mountain, S 62 E. IX, N 35 E.

We found here a large gasser situated on a long fissure. Many small cracks in the vicinity were emitting steam at 100° C. There were no conspicuous deposits. The temperature at the surface was 304° C. Photograph. 3742.

No. 31. T. 210° C. Baked Mountain, S 60 E. IX, N 20 E. Needle Peak, N 71 W.

Two large columns of gas, which registered 210° C. and 205° C., were conspicuous among numerous minute hissing steam jets. The area was not conspicuously colored, being covered with wind-blown ash. Photographs 3743, 4142.

No. 32. T. 323° C. Baked Mountain, S 64 E. IX, N 5 E. Needle Peak, N 64 W.

The immense volume of steam issuing from this fumarole first drew our attention to this one. It was the most conspicuous vent in the lower (north) half of the mud flow. No other fumaroles were near and its large irregular mouth, which rose 15 to 20 feet above the Valley level and emitted a huge column of rolling steam and gas, made it a very striking vent. The hot active area was so large that it was impossible to do more than work around some of the outer crevices, leaving the temperature in the center of the column to conjecture. In the subordinate fissures we found temperatures of 225° C., 304° C., 220° C., 304° C., 323° C. and 294° C. See page 274.

No. 33. T. 432° C. Baked Mountain, S 62 E. IX, N 15 E. Needle Peak, N 62 W.

The main body of the stream flowing from the Valley under Knife Peak cuts across the area of No. 33. An enormous quantity of rolling steam and vapors, which had attracted our attention from the first, came from this area. On arriving, we found the whole area on both banks of the creek steaming. Most of the orifices were minute, but after a search of several minutes, we found one large enough to receive the thermocouple, where we found a temperature of 432° C., the highest we observed anywhere in the Valley. The deposits were very hard white material, but the throats were invariably purplish brown, with occasional small masses of deposit resembling blue or green glass. Other crevices round about gave temperatures of 392° C. and 382° C. Photographs 3744, 3745, 4144, 4145 (See page 276).

Photograph by Paul R. Hagelbarger

FUMAROLE 22.

This fumarole was about eight feet in diameter. The main column of steam did not condense until twenty feet from the opening. With the thermocouple hung over the windward side of the hole, as in the picture, we obtained a temperature of 343° C.

No. 34. T. 159° C. 111, N 14 E. IX, N 34 E. Baked Mountain, S 66 E.

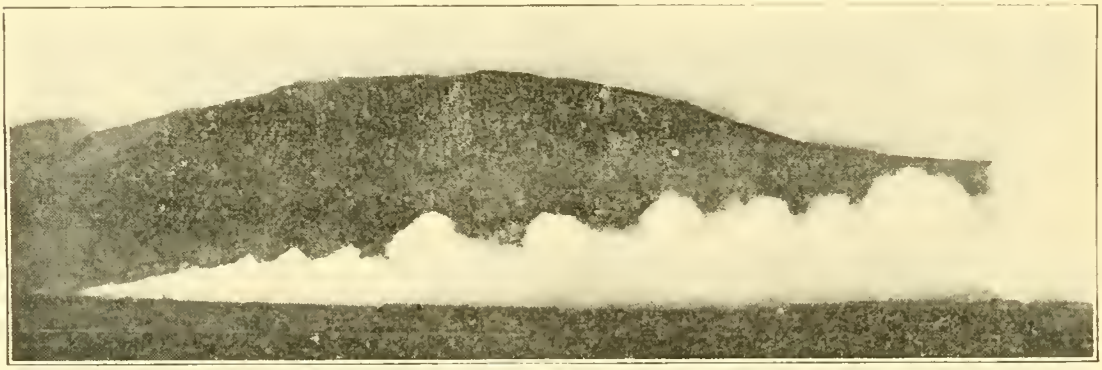
Between Fumarole 33 and Camp VIII we followed the easterly bank of the River Lethe Canyon and recorded a temperature of 159° C. in one of the many steam masses so conspicuous along this stream. We stopped at a number of openings that gave a temperature of only 100° C. We noticed no conspicuous deposits in this vicinity because the area was covered with a thin layer of wind-blown ash.

No. 35. T. 245° C. 111, N 20 E. X, S 60 E. XXX, S 20 W.

This steamer was on the bank of the River Lethe, and was similar to No. 34 in appearance, except that the temperature was higher. The mouth of the fumarole was about 12 to 14 inches in diameter and surrounded by hard baked mud, without deposits. Surface temperature 245° C.

No. 36. T. 245° C. IX, N 22 W. Mt. Mageik, S 26 W. X, S 51 W.

This fumarole was on the east bank of the canyon formed by the stream flowing out of the Knife Peak Valley, and marked the upper end of the impassable mud canyon which this stream forms. The main vents were surrounded by quite an area of steaming ground. The deposits were red and yellow, around the larger and hotter vents. Temperatures of 245° C., 171° C., 181° C. were recorded. Photograph 4552.



Photograph by Robert F. Griggs

FUMAROLE 32 FROM A DISTANCE.

The man silhouetted against the steam near the vent gives the scale. Although the outlying cracks accessible to our thermocouple registered only 323° C., this place has every appearance of being hotter than No. 33, where the highest temperature measured in the Valley was found.

No. 37. T. 342° C. 100 yards east of No. 36.

This fissure was nearly overlooked, as it appeared no hotter than No. 36. However our inquisitiveness was rewarded in discovering that it had a surface temperature of 342° C. The mud here had a crack 100 yards long and the temperatures at various places along this crack were 284° C., 294° C., 314° C. and 342° C. The deposits were yellow and brown near the mouth of the vents while a few feet away from the line of the fissure the ground was ordinary gray ash.

No. 38. T. 100° C. IX, N 39 W. X, S 82 W. XI, S 3 W.

This mass of steam from a distance suggested a temperature of 300° C. at least, but although we tried every crack and crevice in an area of an acre or more, at no place did we succeed in securing a temperature above 100° C. The ground here was covered with a grayish, bluish-black mud about eight inches deep that remained nearly 100° C. in temperature and very disagreeable to work ankle deep in. This marked the northern limit of these mud blanketed areas. Photographs 3753, 3755, 4148, 4150.

No. 39. T. 122° C. X, S 65 W. Mt. Mageik, S 20 E.

A single isolated fumarole caught our attention and, as it seemed so far away from the Valley proper and so close under Knife Peak, we thought that the extra time required to go to it would be rewarded with a high temperature. We certainly were disappointed, however, when the finger of the pyrometer stopped at 122° C. Soft wind-blown ash and pumice surrounded this fumarole. The throat was brownish in color and not very hard in texture. Photographs 3757, 3758.

No. 40. T. 191° C. X, S 38 W. Mt. Cerberus, S 37 E.

This was the first vent on a line of steamers and gassers that lay south of Station IX, near the edge of the mud flow. The ridge that marks the fissure line is broken in many places by the formation of eruptive craters. Several crevices showed only 100° C., but two were hotter, being 191° C. and 112° C. The throats of these two were red, but not otherwise conspicuously colored.

No. 41. T. 254° C. 500 yards south of No. 40.

We were drawn to this region by the copious steaming of No. 40, but, failing to find a high temperature in its steam, were about to pass on when the steam from No. 41 caught our eye. It did not condense for three or four feet from the mouth of the vent, so we knew it must be hot. There were brown and white deposits in and around the throat of the fumarole. The temperature recorded was 254° C. at the mouth of the vent. Photograph 4150.

No. 42. T. 221° C. X, S 26 W. Mt. Mageik, S 26 E. Needle Peak, N 75 W.

This line of craters was close to No. 41. In No. 42 three craters lay in a line, about 20 feet apart, but only the middle one was accessible, as the others were too deep and funnel shaped. This one registered 221° C. and had a dark red and orange throat about one foot in diameter. The crater, which was about three feet deep, had a rim of about 50 feet in circumference. The throat was in one side of the bottom of the crater.

No. 43. T. 100° C. Mt. Mageik, S 28 E. X, S 29 W.

Although registering only 100° C., this fumarole, at the vanishing point of a small creek, was located because of its conspicuousness. The steam rushed forth with great pressure and roared from many cracks in the vicinity, indicating perhaps a higher temperature below the surface. No deposits were noticed, probably being covered up by the shifting ash and sand.

No. 44. T. 100° C. Mud Volcanoes, first area. IX, N 13 W. Mt. Mageik, S 31 E. X, S 23 W.

From a distance this appeared as a gentle area of steamers. It was not until we had approached the center of the area, waist deep in steam, blown close to the ground by the wind, that we realized it was different.

Globules of blue mud shot into the air with a pop and fell back into its basin with a splash, only to be followed by many similar outbreaks all around us. Going to windward we saw the seat of the trouble. The ground was covered with boiling blue mud pots, some with a consistency of well cooked mush, while in others the boiling water was almost clear. It was impossible to secure satisfactory pictures of the performance, because of the thick blanket of rising steam that covered an area of an acre or more. The mud was blue black. The temperature was that of steam, 100° C. Photographs 4146, 4151, 4152, 4558, 4560.

Photograph by Paul R. Hagelbarger

PLACING THE THERMOCOUPLE IN FUMAROLE 33.

This inconspicuous crack, with the thermocouple placed as in the picture, gave a temperature of 432° C., the highest measured in the valley. The ground near the fissure was too hot to stand on very long, so we supported the cold junction of the thermocouple on a spade.

No. 45. T. 412° C. IX, N 10 W. X, S 19 W. Mt. Mageik, S 35 E.

Between No. 33 and No. 36 and the east bank of the canyon from Knife Peak Valley was a conspicuous steamer. As we approached it, 200 yards to the eastward, we came upon the end of the fissure which gave forth a big column of steam where it was crossed by the Canyon. The deposits here were light colored. At different places in the small cracks in the roof of the fissure the temperatures were 289° C., 318° C., 387° C., 412° C., 402° C., 397° C. The main steamer, we found, had a temperature of 360° C. at the surface of the ground.

No. 46. T. 171° C. 500 yards south of No. 22.

This fumarole was on the same line of activity as No. 22, and was very similar to No. 22 and No. 47. It was a large circular hole in the roof of a wide fissure probably caused by a cave in. There was an immense volume of steam coming from it. In the pictures, this and the next appear as one opening. The temperature recorded from it was 171° C. This was obtained by hanging the thermocouple over the edge of the cavity, and does not in our opinion correctly represent the temperature. It was, however, the only place accessible with the wind in the southeast, as it was when we visited it.

No. 47. T. 309° C. 50 feet south of No. 46.

This fumarole was on the same line of activity and similar to No. 46, except perhaps that the opening was larger and emitted a greater volume of steam. This one was easier to work with because the wind was favorable. With the thermocouple bent and hung eight feet over the edge of the hole, the temperature was 309° C.

Photograph by Jasper D. Sayre

A MUD POT IN AREA 48.

Boiling mud may be seen spattering up from the bottom, left and right.

No. 48. T. 100° C. Mud Volcanoes, second area. Mt. Cerberus, S 48 E. Baked Mountain, S 84 E. 86, S 3 W. X, N 63 W.

This was a nest of mud pots, boiling and sometimes spouting three feet into the air. A crater ring of considerable size had been formed around some of them. The mud was a chocolate brown, and no conspicuous deposits or incrustations were noticed. All had a temperature of 100° C. Photograph 3693 (See cut above).

SUMMARY AND DISCUSSION OF RESULTS.

1. The highest temperature measured was 432° C. This, (No. 33), was found in a small and relatively inconspicuous crack which one would have expected to be cooler than great volcanoes like No. 32, in which the center of the steam column was inaccessible to our instruments.

2. We measured 102 vents with temperatures above 100° C. in the 48 areas which we visited and located. Nine vents with temperatures between 390° and 440° C. were measured; 28 vents between 290° and 390° C.; 49 vents between 190° and 290° C.; 16 vents between 100° and 190° C.; together with many hundred measured but not recorded, with steam at the boiling point. The relatively small number of vents between 100° and 190° C. is to be interpreted as due to the difficulty of working the thermocouple between these temperatures, because of short circuiting by condensing steam.

3. The temperatures of a number of chimney-like vents were distinctly highest at the surface of the ground where the hot gases met the air. The greatest difference was observed in No. 23, which was 107° C. hotter at the surface than three feet down the hole, the temperatures being—surface, 352° C.· three feet down, 245° C. Such differences were observed in Nos. 3, 4, 5, 9, 11 and 23.

This increase of temperature at the surface is interesting in view of the fact that the opposite was expected. (a) Since the gas presumably issues from a molten magma beneath the surface, one would expect a steady lowering of the temperature gradient from the hot magma to the cold air. (b) Since the gas issues under considerable pressure, roaring and hissing as it rushes out of the orifice, its expansion if carried out adiobatically would considerably lower the temperature.

While it would be easy to hypothecate reactions of gases that would liberate heat enough to produce the observed rise in temperature, such a speculation could have little value until the gases can be examined chemically. The analyses now under way and projected by the Geophysical Laboratory of the Carnegie Institution ought to throw much light on this question.

A KEY TO THE SPECIES OF WISCONSIN ANTS, WITH NOTES ON THEIR HABITS.

A. C. Burrill and M. R. Smith.

The writers are particularly indebted to Dr. W. M. Wheeler, of Harvard University, for the identifications cf a number of the species here given and for the frequent references to his notes.

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Mr. H. S. Barber, U. S. Bureau of Entomology, for the identification of Coleopterous larvæ.

Subfamily Formicidæ.

1. Abdominal pedicel consisting of a single segment.......... 2.
   Abdominal pedicel consisting of two segments.......... 3.
2. Cloacal orifice terminal, surrounded by a fringe of hairs..... *Camponotinæ.*
   Cloacal orifice ventral.......... 4.
3. Frontal carinæ very close together, almost vertical, not covering antennal insertions; eyes small or absent.......... *Dorylinæ.*
   Frontal carinæ not as above; eyes rarely vestigial or absent...... *Myrmicinæ.*
4. No constrictions between the first and second gastric segments; anal glands present, which produce a secretion with a rancid butterlike odor.... .... *Dolichoderinæ.*
   Gaster with a distinct constriction between the first and second segments; frontal carinæ separated or close together.......... *Ponerinæ.*

Subfamily Camponotinæ.

1. Antennæ with nine joints........................... *Brachymyrmex* Mayr.
   Antennæ with more than nine joints....................................2.
2. Workers polymorphic, pronotum flattened............. *Camponotus* Mayr.
   Workers not polymorphic, though of variable size........................3.
3. Large robust ants with three prominent ocellar spots on vertex of the head, ... *Formica* Linn.
   Smaller, more slender ants with less prominent ocellar spots on vertex of the head...4.
4. Mesonotum sub-cylindrical .... *Prenolepis* Mayr.
   Mesonotum not sub-cylindrical..5.
5. Maxillary palpi six jointed........................... *Lasius* s. str. Fabr.
   Maxillary palpi three jointed................. subgen. *Acanthomyops* Mayr.

Genus *Brachymyrmex* Mayr.

B. heeri depilis Emery.

A small, pale yellowish species with nine jointed antennæ. It is the smallest of the Wisconsin ants recorded in this paper.

The workers build their nests under stones in shady woods and attend root *Coccids* and *Aphids*.

Subfamily Camponotinæ.

Genus *Camponotus* Mayr.

1. Clypeus with a notch in the middle of its anterior border................ .... (*fallax* and its varieties) 2.
   Clypeus without such a notch..3.
2. Form slender; head, thorax and abdomen smooth shining black, practically devoid of hairs except for the fringe of hairs on the posterior edge of each segment of the abdomen.................. *fallax* var. *nearcticus* Emery.
3. Color black; head and thorax sparsely covered with large yellow hairs; the abdomen with numerous large hairs and rather pubescent giving it a bronzed appearance............................ *herculaneus pennsylvanicus* De Geer.
   Color yellow and black or red and black....................................4.
4. Yellow or brownish red in color, gaster dark, head much darker than either, ... *castaneus* subsp. *americanus* Mayr.
5. Thorax dark red, head and abdomen smooth shining black............... .... *herculaneus ligniperda* var. *noveboracensis* Fitch.
   Thorax black, mottled with red, the latter color being confined to the posterior part of the thorax........... *herculaneus* var. *whymperi* Forel.

C. herculaneus subsp. **pennsylvanicus** De Geer.

This ant is the most widely distributed species of the genus, ranging from southern Canada over the North Atlantic and Middle Western States as far west as Texas and South Dakota; for this reason it has been more often noticed than the other members of this group.

Nests are built in logs, stumps or the dead wood of standing trees; occasionally they nest in houses where they may do considerable damage by tunneling in the wood.

C. herculaneus ligniperda var. **noveboracensis** Fitch.

The workers of this beautiful form have a black head and gaster and a dark red thorax. The body surface is rather smooth and shining.

This species ranges across the continent from the Atlantic to the Pacific, between Nova Scotia, its northern-most limit and Maryland, its southern-most limit. In the Atlantic States it nests at high elevations. It is a wood nesting species also.

Workers have been found attending *Thelia bimaculata* on locust at Madison, Wisconsin.

Staphylinids found occurring in their nests were identified by Dr. A. Fenyes, of Pasadena, California, as *Anomognathus cuspidatus* Fabr.

C. castaneus var. **americanus** Mayr.

These ants are very variable in coloration. The Wisconsin specimens before the writer are reddish brown, with a black head.

Nets which are built under stones in the woods, contain numerous individuals.

C. americanus ranges over the Atlantic States and as far west as Texas and Illinois.

C. herculaneus var. **whymperi** Forel.

This form is somewhat variable in coloration, with portions of the body either red or black. The specimens examined were black with the exception of the posterior portion of the thorax, legs and petiole, which are light yellowish red.

C. whymperi nests at high elevations usually; when found in the lowlands, it occurs in cold tamarack bogs, or the cold woods of the Alleghanies, etc. For the reasons given, it appears to be a Boreal or Alpine form. Their nests, consisting of large colonies, are built in logs and stumps.

C. fallax var. **nearcticus** Emery.

These ants are much more smaller and slender than are those just mentioned. They are smooth, shining black.

Nests consisting of a few individuals are found under the bark of trees.

Genus *Lasius* Fabr.

1. Maxillary palpi with six joints.............................*Lasius* s. str. 2.
   Maxillary palpi with three joints..........................subgen. *Acanthomyops* 4.
2. Scapes and legs with erect hairs....................*niger* var. *neoniger* Emery.
   Scapes and legs without erect hairs...3.
3. Body brown in color............................*niger* var. *americanus* Emery.
   Body yellow in color; hairs on the abdomen subdepressed................
   ....*mixtus* var. *aphidicola* Walsh.
4. Petiole low and blunt..*latipes* Walsh.
   Petiole higher and thinner...5.
5. Gaster with abundant long hairs..................................*claviger* Roger.
   Gaster without abundant, long hairs........................*interjectus* Mayr.

L. niger var. **americanus** Emery.

This species is the most abundant of all our North American ants, occurring throughout the country except in the extreme southern and southwestern section. It shows great adaptability in its nesting habits and may be found in the damp rotten wood of forests or in the gravelly soils of open fields. In the open fields their nests consist of small craters.

The workers are exceedingly fond of the sweet secretions of aphids or other honey dew secreting insects and may often be found in attendance upon such forms. Their relation to the corn and cotton root louse, *Aphis maid radicis*, has caused this species to be considered of great economic importance. Dr. Forbes, of Illinois, has published some very interesting reports on the habits and life economy of this species.

Workers of Lasius americanus have been collected that were heavily infested with a parasitic fungus known as *Laboulbenia formicarium* Thaxter.

L. niger var. **neoniger** Emery.

This ant may easily be mistaken for *L. americanus* from which it differs by the presence of erect hairs on the antennal scapes and legs.

The habits of the two species are the same.

Workers have been observed attending *A. forbesii* on strawberry plants.

L. umbratus mixtus var. **aphidicola** Walsh.

This is a rather robust, yellowish brown species with subdepressed hairs on the gaster.

Nests are constructed under stones or in the base of stumps in damp shady woods. The colonies are rather large and are given to cultivating subterranean aphids.

Subgenus *Acanthomyops* Mayr.

L. (A.) interjectus Mayr.

The workers of this species are yellow and robust, with an agreeable body odor somewhat similar to that of lemon verbena. This is the largest species of the genus.

Nests are built under stones, in logs or in stumps. The workers which are very numerous in the colonies attend aphids underground.

L. (A.) claviger Roger.

This species is smaller than *L. interjectus* and possesses abundant long hairs on the gaster. The lemon verbena like odor is also present about the workers.

L. claviger is the most abundant species of the subgenus *Acanthomyops*. It nests under stones.

L. (A.) latipes Walsh.

Females of this form are dimorphic. One of the forms being very hairy and possessing much flattened femora and tibiæ.

Nests are constructed under stones.

Genus *Prenolepis* Mayr.

P. imparis Say.

This species is the largest ant of the genus, measuring from 3–4 mm. in length. It is also the most widely distributed, ranging from the Atlantic to the Pacific in the Transition Zone. The typical form is dark brown, while the variety is much smaller and paler.

The workers are exceedingly fond of sweets, aphid excretions, etc., and are very commonly found attending aphids, coccids, and membracids. When the workers are full of honey dew, their abdomens are very much distended; this when they are walking gives them the appearance of swaggering like a drunken man.

This species has been observed to be much of a house pest in the South Atlantic States.

Their nests, which are located in moist clay like soils, are small craters made of irregular pellets, which resemble the pellets of the ants of the subgenus *Trachymyrmex*. A colony consists of from 300 to 400 individuals. The males and females pass the winter in the colony nest and take their nuptial flights early in the spring.

Subgenera and Groups of the Genus *Formica* Linn.

1. First funicular joint about as long as the second and third taken together. Small, rather smooth, shining dark colored species.................. ....Subgenus *Proformica* Rusky.
   First funicular joint shorter than the second and third taken together.... ....Subgen. *Formica* Linn. 2.
2. Anterior edge of clypeus notched or emarginate in the middle..*sanguinea* group.
   Anterior edge of clypeus entire, rounded or subangularly produced in the middle...3.
3. Sides of head subparallel, posterior border deeply and widely excised.... ....*exsecta* group.
   Sides of head converging anteriorly, posterior border straight, convex or feebly excised...4.
4. Body robust. Head of largest individuals not or hardly longer than broad. Body opaque, color light or dark red with black gaster........*rufa* group.
   Body more slender. Head of largest individuals longer than broad. Petiole narrow, rather thick and with a blunt border. Color and sculpture variable..5.
5. Thorax rather short. Scapes distinctly curved at the base. Petiole flattened behind...*fusca* group.
   Thorax longer. Scapes slender, very slightly curved at the base. Petiole convex behind..................................Subgen. *Neoformica.*

Subgenus *Proformica* Rusky.

F. (P.) neogagates neogagates Emery.

A small, smooth, dark or black shining species with light reddish colored mandibles, antennæ and legs. Sometimes the cheeks and clypeus are light red in color.

The workers of this species resemble the small workers of *F. subpolita* and for this reason the two species are sometimes confused. *F. neogagates* differs from the former in its more abundant, more finer and paler pilosity.

The ants nest in small colonies under stones and are very timid. They are a Sub-Boreal species and are not often found at low elevations.

F. sanguinea and its various subspecies make slaves of this species.

Subgenus *Formica* Linn.

Sanguinea Group.

1. Head long and narrow. Color of head, thorax and petiole brownish testaceous. Body opaque......................................*pergandei* Emery.
   Head hardly longer than broad...2.
2. Hairs nearly always absent on the dorsal portion of the thorax and petiolar border; short and sparse on the head and gaster..*sanguinea subnuda* Emery.
   Hairs present on the dorsal portion of the thorax and petiolar border; longer and more numerous on the head and gaster...............................3.
3. Gaster black. Petiole with sharp superior border, which is usually notched in the middle..............................*sanguinea rubicunda* Emery.
   Gaster brown. Petiole with blunt superior border, which is usually entire. ....*sanguinea subintegra* Emery.

F. pergandei Emery.

The writers have not seen specimens of this species, although it is known to occur in Wisconsin. Wheeler states that this species is rare.

F. sanguinea subnuda Emery.

This species is a Boreal or Alpine form and is not very easily distinguished from *F. aserva*.

It makes slaves of *F. fusca* vars. *subsericea*, *argentea*, *subaenescens*, and *gelida*.

F. sanguinea rubicunda Emery.

Workers of this subspecies vary in color and character of pilosity. This subspecies is not as abundant as the subspecies *subintegra* and *subnuda*.

F. subsericea, *neogagates*, *schufussi* and *neocinerea* are its slaves.

F. sanguinea subintegra Emery.

F. subintegra may be distinguished from *rubicunda* by the smaller size, peculiar color of the gaster and the narrower blunter petiole of the worker.

It is the common form of *sanguinea* in the Eastern States and Canada at low elevations in warmer situations.

The following species are made slaves of by *F. subintegra*, *F. fusca* and vars. *subsericea*, *subaenescens*, *F. cinerea neocinerea*, *neogagates*, *vidua; F. pallide-fulva schaufussi*, *nitidiventris*, *fuscata* and *incerta*.

Exsecta Group.

1. Posterior portion of the head black.........................*ulkei* Emery.
   Posterior portion of the head not black.....*exsectoides exsectoides* Forel.

F. ulkei Emery.

Wheeler states that this species is peculiar to the Canadian fauna but is very rare in the Transition Zone.

The nests are flattened mounds a foot or more in diameter, composed of earth and vegetable matter.

A larva of *Coscinoptera dominicana* Fabr. was found in the nest of this species.

F. exsectoides exsectoides Forel.

F. exsectoides is the famous mound building ant of the Alleghany Mountains, of whose interesting habits Rev. H. C.

McCook has made a thorough study. The nests are conical mound from two to ten feet in convex diameter, consisting principally of earth. They are located in open places in the woods.

The workers are very ferocious and will attack anyone trespassing on their domains. They kill other ants by decapitation.

This species is a temporary parasite of *F. fusca* var. *subsericea*.

Rufa Group.

1. Flexor of tibiæ with erect hairs..2.
   Flexor surface of tibiæ without erect hairs................................3.
2. Thorax of large workers bright red like the head or at the most very feebly infuscated..*rufa aggerans* Wheeler.
   Thorax of small workers deeply infuscated. Pubescence on the gaster weaker. ....*rufa aggerans* var. *melanotica* Whlr.
3. Head and thorax of small workers spotted with brown. Frontal area shining, ...*rufa obscuripes* Forel.
   Head and thorax of small workers generally without brown spots; when spotted, the spots are pale. Frontal area slightly shining.......... ....*truncicola integroides* Emery.

F. rufa aggerans Wheeler.

This robust species is the common thatching ant of the Western States. Their nests are small, more or less flattened mounds covered with coarse straws, sticks or vegetable matter.

The Junior writer has observed this species attending *Pubilia concava* on *Helianthus* sp.? and *Thelia bimaculata* on locust.

F. rufa aggerans var. **melanotica** Wheeler.

This variety possesses the same nesting habits as the species just mentioned except that their nests are smaller, being from a foot to a foot and a half in diameter and are constructed in grassy fields.

The Senior author has observed this species having its nest covered with the larvæ of *Coscinoptera dominicana* Fabr.

F. rufa obscuripes Forel.

Wheeler states that this form is imperfectly known. The absence of erect hairs on the tibiæ of the legs is not a very strong character for separating this species from other members of the group.

Nests of this ant are similar to those of *F. aggerans*.

The species is peculiar to the Northwestern States, occurring at elevations between 5,000–8,000 feet.

F. truncicola integroides Emery.

The workers of this species pile large quantities of vegetable debris about stumps and logs and make their nests in the stumps and bogs.

The writers have not seen specimens of this ant from Wisconsin.

Fusca Group.

1. Gula with erect hairs. Top of head much darker than the other portions of the head.......................*cinerea cinerea* var. *neocinerea*. Wheeler.
   Gula without erect hairs. Pubescence on the gaster dense and silky...... ....*fusca* var. *subsericea* Say.

F. cinerea cinerea var. **neocinerea** Whlr.

The workers build flattened mounds in the meadows and bogs of the Northwestern States.

The Junior writer has observed this species attending *Pubilia concava* on *Helianthus* sp. It has been observed by the Senior writer to attend *A. pomi* on apple.

F. fusca var. **subsericea** Say.

This beautiful shining species is one of the most abundant ants in North America. It is very widely distributed throughout the Eastern States.

The workers are cowardly ants and are made slaves of by ants of the groups *sanguinea*, *rufa* and *exsecta*. Although they feed on insects to a large extent, the workers are also given to attending aphids.

Nests are built under stones or in low flat mounds in sunny places. Their nests often disfigure beautiful lawns in the Northern States.

F. subsericea has been observed to attend the following aphids: *Chaitophorus populicola* on poplar, *C. negundinis* on box elder, *C. nigrae* on *Salix fragilis* and the membracid, *Pubilia concava* on *Helianthus* sp.

Subgenus *Neoformica*.

1. Erect hairs present on the gula and petiole..................................2.
   Erect hairs absent on the gula and petiole..................................3.
2. Hairs on the gula and petiole numerous and conspicuous.............. ....*pallide-fulva schaufussi* Mayr.
   Hairs on the gula and petiole few, often lacking on one or the other; head, thorax and gaster darker.....*pallide-fulva schaufussi* var. *incerta* Mayr.
3. Head and thorax brown or reddish brown, gaster shining.............. ....*pallide-fulva nitidiventris* Emery.
   Head and thorax darker, body often less shining...................... ....*pallide-fulva nitidiventris* var. *fuscata* Emery.

F. (N.) pallide-fulva schaufussi Mayr.

A very common form throughout the Northeastern States. Their colonies, which are fairly large, consist of nests under stones or in craters in open sunny fields, pastures, etc.

The workers are very timid. They feed on dead insects and the excretions of aphids.

F. (N.) pallide-fulva schaufussi var. **incerta** Emery.

This variety has habits similar to those of *F. schaufussi*, but ranges farther west than that species. There is a considerable variation in the individuals from different colonies or localities and it is not always easy to separate this species from the species *nitidiventris* or *schaufussi.*

F. (N.) pallide-fulva nitidiventris Emery.

This species has a range that nearly coincides with that of *incerta*. The habits of *F. nitidiventris* are similar to those of the species just discussed.

F. (N.) pallide-fulva nitidiventris var. **fuscata** Emery.

The workers are much darker than those of *F. nitidiventris*. The habits of the two, are however, practically the same.

Subfamily *Myrmicinæ*.

1. Postpetiole joined to the dorsal surface of the gaster...*Cremastogaster* Lund.
   Postpetiole not joined to the dorsal surface of the gaster..................2.
2. Eyes vestigial..................................*Stenamma* Westwood.
   Eyes not vestigial..3.
3. Antennæ with two jointed club.........................*Solenopsis* Fabr.
   Antennæ without a two jointed club..................................4.
4. Epinotum with spines..5.
   Epinotum without spines..............................*Monomorium* Mayr.
5. Antennæ with a three jointed club...................................6.
   Antennæ without a three jointed club................................7.
6. Prothorax distinctly angular anteriorly................*Tetramorium* Mayr.
   Prothorax not angular anteriorly; small ants that nest in galls, nuts, etc.. ....*Leptothorax* Mayr.
7. Promesonotal suture very distinct dorsally.............*Aphænogaster* Mayr.
   Promesonotal suture not very distinct dorsally; head and thorax coarsely rugose reticulate..*Myrmica* Latr.

Genus *Cremastogaster* Lund.

C. lineolata Say.

This species ranges over the whole of North America from the Atlantic to the Pacific to an altitude of about 7,000 feet in the Rocky Mountains. There are a number of varieties and subspecies of this form.

The workers are very fond of aphid excretions and like substances and for this reason are commonly found in attendance upon honey dew secreting *Hemipterans*.

Their nests may be found in the soil under rocks, in dead wood, or under the bark of trees. The nests have a very peculiar rank odor.

The workers when in large numbers are rather courageous and will sting or bite. They have a peculiar habit of carrying their gasters pointing upward, which much resembles the habits of Staphylinids.

Genus *Leptothorax* Mayr.

L. acervorum subsp. **canadensis** Provancher.

A small brownish species with dark gaster, having the thorax faintly, but distinctly impressed at the mesoepinotal suture.

Wheeler states that it is a rather rare boreal form, which nests under bark in small colonies.

Genus *Tetramorium* Mayr.

T. guineese Fabr.

This species is reddish yellow with the exception of the gaster which is almost black. The carinal grooves extend to within a short distance of the posterior corners of the head.

Workers were collected in a greenhouse at Milwaukee, Wisconsin. Their habits are similar to those of *T. caespitum.*

Genus *Solenopsis* Westwood.

S. molesta Say.

The minute workers of this species are yellow and have distinct two jointed antennal clubs.

This ant is very common to the Northern and Eastern States. In Kansas it is known to attack corn and related cereal crops. The workers gnaw into the kernels of the grain and destroy the germinating portions, thus seriously damaging the crop. Occasionally this species attacks small fruits, like strawberries and raspberries and injures the fruit by eating out irregular holes.

Genus *Monomorium* Mayr.

1. General body color shining black........................*minimum* Buckley.
   General body color yellowish with gaster slightly infuscated..*pharaonis* Linn.

M. minimum Buckley.

The small shining black workers of this species make small crater-like nests in sandy or gravelly soil. The writers have also found them nesting in rotten wood.

Workers are frequently observed crawling over flowers, where they are in search of the extra floral nectaries.

M. pharaonis Linn.

This little yellow or red house ant is an imported species, which has become quite common in houses, where it feeds on sweets, breads, meats, etc. The writer has seen several flats vacated because of the ravages of this pest.

Genus *Aphaenogaster* Mayr.

1. Epinotal spines as long as the base of the epinotum, or longer; color red.. ....*tennesseensis* Mayr.
   Epinotal spines not as above; shorter than one-half the base of the epinotum. 2.
2. Color reddish brown............................*fulva* subsp. *aquia* Emery.
   Color pitchy black..........................*fulva aquia* var. *picea* Emery.

A. tennesseensis Mayr.

The beautiful workers of this form occur in the Northeastern States, where they live in mixed colonies with *A. fulva* and its varieties. Their nests are usually found in rotten wood.

This species bears a close resemblance to *A. lamellidens* and has been mistaken for it. *A. lamellidens*, however, does not occur as far north as this species.

A. fulva subsp. **aquia** Emery.

A slender brown species that nests under stones in the woods. The workers feed on dead insects.

A. fulva aquia var. **picea** Emery.

A darker variety of the subspecies. The habits of this and the former are the same.

Genus *Myrmica* Latr.*

1. Antennal scape with a tooth or transverse lamina at the base...scabrinodis Nyl. and varieties. 2.
   Antennal scape without a tooth or lamina at the base..*rubra brevinodis* Emery.
2. Color of body pale red; nest built in dry open fields...*scabrinodis* var. *sabuleti* Emery.
   Color of body dark; antennal lamina prominent; nest built in the woods.............................*scabrinodis schencki* var. *emeryana* Forel.

M. scabrinodis Nyl.

A palearctic species with several varieties.

M. scabrinodis var. **sabuleti** Emery.

This is a pale red variety of the species. It nests in sandy or gravelly sunny places and is often seen in attendance upon aphids.

M. scabrinodis schencki var. **emeryana** Forel.

A darker form of *scabrinodis* which nests in the wood. The workers have a very pronounced lobe on the scape.

M. rubra brevinodis Emery.

This species seems to abound in sections where the climate is rather cold and is often collected at high altitudes. It is the host of *L. emersoni*, another ant.

Subfamily Dolichoderinæ.

1. Epinotum strongly concave posteriorly..............................*Dolichoderus* Lund. subgen. *Hypoclinea* Mayr.
   Epinotum not concave posteriorly; petiole absent or vestigial...*Tapinoma* Foerster.

Genus *Dolichoderus* Lund.

D. (Hypoclinea) taschenbergi Mayr. var.

Small, rather robust, shining black ants with the posterior portion of their epinotums concave.

This species is an arboreal type and is commonly found attending aphids or scales on trees. When crawling over the trees, they have the habit of moving in files.

Genus *Tapinoma* Föerster.

T. sessile Say.

The workers of this form are slender black ants that nest in the ground or in rotten wood. When nesting in the ground they construct crater-like nests. Although they feed on dead insects, the workers also have a fondness for attending aphids.

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* Dr. W. M. Wheeler kindly furnished the key to the species.

Subfamily PONERINÆ.

1. Mandibles long and slender, with coarse bidenticulate teeth.......... ....*Stigmatomma* Roger.
   Mandibles not long and slender or with coarse bidenticulate teeth.... ....*Ponera* Latr.

Genus *Ponera* Latr.

P. coarctata pennsylvanica Emery.

The workers of this species are small slender ants with vestigial eyes.

The workers nest under stones in rotten logs, vegetable mold, etc.

Genus *Stigmatomma* Roger.

S. pallipes Haldeman.

This species has workers which are slender, dark brown in color, and have the mandibles, antennæ, and legs paler.

The workers are hypogaeic in habits and occur only in rich damp woods under stones, logs, etc. It is not a common species as the form is rather primitive. The colonies are small, being composed of from forty to fifty individuals.

ADDITIONS TO THE CATALOG OF OHIO VASCULAR PLANTS FOR 1918.*

John H. Schaffner.

During the past year a number of botanists have made interesting collections of native and introduced plants, specimens of which have been placed in the State Herbarium. Strange plants continue to appear in Ohio from year to year and some of these will, without doubt, finally become a part of our normal flora. There are probably also quite a number of uncommon native plants which have not yet been reported and much work remains to be done before the geographical distribution of our indigenous species will become fairly well known. The natural geographic boundaries marked out by certain species will be of great value in delimiting the natural agricultural and horticultural areas of the state; so that, while individual observations may not in themselves be of great value, many observations over the entire state will eventually give us knowledge of great importance. It is hoped, therefore, that the botanists of the state will continue work along this line as in the past and send specimens of the unusual species to the State Herbarium as well as to herbaria that may exist in local institutions.

The Catalog of Ohio Vascular Plants was issued by the Ohio Biological Survey in March 1914, and during the five years since then additions and corrections have been published annually. Including the present list, 47 new species and varieties have been added, and authentic specimens have been secured of many plants on the original list which were not represented in the herbarium. It is especially desired that every species in the catalog be represented by at least one authentic specimen.

63. **Lycopodium complanatum** L. Trailing Club-moss. Beaver Tp, Noble County. S. C. Shuman.

156. **Eleocharis acuminata** (Muhl.) Nees. Flat-stemmed Spike-rush. Barnesville, Belmont County. Emma E. Laughlin.

170. **Scirpus planifolius** Muhl. Flat-leaf Club-rush. Lore City, Guernsey Co. Emma E. Laughlin.

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*Papers from the Dept. of Botany, The Ohio State University, No. 105.

337. **Eragrostis purshii** Schrad. Pursh's Love-grass. General in Ohio.
340. **Eragrostis capillaris** (L.) Ness. Capillary Love-grass. Barnesville, Belmont Co. Emma E. Laughlin.
403. **Muhlenbergia umbrosa** Scribn. Wood Muhlenbergia. Fulton Co. R. A. Cave.
451. **Syntherisma filiforme** (L.) Nash. Slender Crab-grass. Columbus, Franklin Co. Freda Detmers.
454.1. **Echinochloa frumentacea** (Roxb.) Link. Billion-dollar-grass. Escaped. Barnesville, Belmont Co. Emma E. Laughlin.
474. **Yucca filamentosa** L. Adam's needle. Hillsboro, Highland Co. Katie M. Roads.
484. **Allium cepa** L. Common Onion. Persistent after cultivation. Hillsboro, Highland Co. Katie M. Roads.
489. **Muscari botryoides** (L.) Mill. Grape-hyacinth. Hillsboro, Highland Co. Katie M. Roads.
520. **Convallaria majalis** L. Lily-of-the-valley. Hillsboro, Highland Co. A common escape from cultivation. Katie M. Roads.
546.1. **Juncus brachycarpus** Engelm. Short-fruited Rush. Bethel, Clermont Co. E. Lucy Braun.
559. **Gemmingia chinensis** (L.) Ktz. Blackberry-lily. Hillsboro, Highland Co. Katie M. Roads.
595. **Liparis liliifolia** (L.) Rich. Large Twayblade. Beaver Tp., Noble Co. S. C. Shuman. Hillsboro, Highland Co. Katie M. Roads.
696. **Radicula sylvestris** (L.) Druce. Creeping Yellow-cress. Anderson's Ferry, Hamilton Co. E. Lucy Braun. Barnesville, Belmont Co. Emma E. Laughlin.
700. **Lepidium draba** L. Hoary Peppergrass. Fairview, Hamilton Co. E. Lucy Braun.
701.2. **Iberis umbellata** L. Common Candytuft. Escaped from cultivation. Hillsboro, Highland Co. Katie M. Roads.
702. **Carara didyma** (L.) Britt. Lesser Wart-cress. Barnesville, Belmont Co. Emma E. Laughlin.
705. **Alliaria alliaria** (L.) Britt. Garlic Mustard. Hartwell, Hamilton Co. E. Lucy Braun.
714. **Conringia orientalis** (L.) Dum. Hare's-ear Mustard. Madisonville, Hamilton Co. E. Lucy Braun.

743. **Sinapis alba** L. White Mustard. Hillsboro, Highland Co. Katie M. Roads.
749. **Brassica oleracea** L. Cabbage. Hillsboro, Highland Co. Katie M. Roads.
754.1. **Cleome serrulata** Pursh. Pink Cleome. Anderson's Ferry, Hamilton Co. E. Lucy Braun.
774.1. **Linum striatum** Walt. Ridged Flax. Bethel, Clermont Co. E. Lucy Braun.
779.1. **Impatiens balsamina** L. Garden Touch-me-not. Persistent after cultivation. Hillsboro, Highland Co. Katie M. Roads.
795. **Acalypha ostryaefolia** Ridd. Hornbeam Three-seeded Mercury. Miamiville, Clermont Co. E. Lucy Braun.
797. **Ricinus communis** L. Castor-oil-plant. Hillsboro, Highland Co. Katie M. Roads.
807. **Dichrophyllum marginatum** (Pursh.) K. & G. Snow-on-the-mountain. Hillsboro, Highland Co. Katie M. Roads.
869. **Viola tricolor** L. Garden Pansy. Escaped. Hillsboro, Highland Co. Katie M. Roads.
870. **Viola odorata** L. Sweet Violet. Hillsboro, Highland Co. Katie M. Roads.
912. **Silene latifolia** (Mill.) Britt & Rend. Bladder Campion. Barnesville, Belmont Co. Emma E. Laughlin.
923. **Vaccaria vaccaria** (L.) Britt. Cowherb. Barnesville, Belmont Co. Emma E. Laughlin.
935. **Mirabilis jalapa** L. Four-o'clock. Persistent after cultivation. Hillsboro, Highland Co. Katie M. Roads.
940. **Celosia cristata** L. Cock's-comb. Hillsboro, Highland Co. Katie M. Roads.
962. **Cycloloma atriplicifolium** (Spreng.) Coult. Tumbleweed. Barnesville, Belmont Co. Emma E. Laughlin.
963. **Kochia scoparia** (L.) Roth. Mock-cypress. Hillsboro, Highland Co. Katie M. Roads.
963.1. **Monolepis nuttalliana** (R. & S.) Greene. Monolepis. From the West. Barnesville, Belmont Co. Emma E. Laughlin.
966. **Salsola pestifer** Nels. Russian-thistle. Barnesville, Belmont Co. Also at Somerton, Belmont Co. Emma E. Laughlin.
984. **Persicaria muhlenbergii** (Wats.) Small. Swamp Persicaria. Addyston, Hamilton Co. E. Lucy Braun.

1037. **Spiraea tomentosa** L. Steeple-bush. Bethel, Clermont Co. E. Lucy Braun.

1070.1. **Crataegus intricata** Lange. Biltmore Hawthorne. Knox, Franklin. Both collected by W. A. Kellerman, 1897 and 1892 respectively. John H. Schaffner.

1071. **Crataegus straminea** Beadle. Allegheny Hawthorn. Omit Knox and Franklin counties from the distribution. The species is known from Hocking Co. only.

1091. **Prunus pumila** L. Sand Cherry. Terrace Park, Hamilton Co. E. Lucy Braun.

1131.1. **Robinia hispida** L. Rosa Acacia. Escaped. Hillsboro, Highland Co. Katie M. Roads.

1174. **Dolichos lablab** L. Hyacinth Bean. Hillsboro, Highland Co. Katie M. Roads.

1200. **Rhexia virginica** L. Virginia Meadow-beauty. Bethel, Clermont Co. E. Lucy Braun.

1214. **Ampelopsis cordata** Mx. Heartleaf Ampelopsis. Cleves, Hamilton Co. E. Lucy Braun.

1225. **Cardiospermum halicacabum** L. Balloon-vine. Hillsboro, Highland Co. Persistent after cultivation. Katie M. Roads.

1232a. **Acer rubrum viridum** Detmers. Cranberry Island, Buckeye Lake, Licking Co. Freda Detmers.

1232b. **Acer rubrum rubrocarpum** Detmers. Cranberry Island, Buckeye Lake, Licking Co. Freda Detmers.

1334. **Ludwigia polycarpa** S. & P. Many-fruited Ludwigia. Addyston, Hamilton Co. E. Lucy Braun.

1386. **Pyrola elliptica** Nutt. Shinleaf Wintergreen. Hillsboro, Highland Co. Katie M. Roads.

1427. **Ipomoea hederacea** Jacq. Ivyleaf Morning-glory. Barnesville, Belmont Co. Also in Washington Co. Emma E. Laughlin.

1430. **Quamoclit coccinea** (L.) Moench. Small Red Morning-glory. In waste places and along lanes. Hillsboro, Highland Co. Katie M. Roads.

1465.1. **Gentiana procera** Holm. Smaller Fringed Gentian. Big Darby Creek, near West Jefferson, Madison Co. Mrs. Bayard Taylor.

1467. **Gentiana saponaria** L. Soapwort Gentian. Bethel, Clermont Co. E. Lucy Braun.

1509. **Physalis pruinosa** L. Tall Hairy Ground-cherry. Hillsboro, Highland Co. Katie M. Roads.

1514.1. **Solanum triflorum** Nutt. Cutleaf Nightshade. From the West. Barnesville, Belmont Co. Emma E. Laughlin.

1515. **Solanum rostratum** Dun. Buffalo-bur. Barnesville, Belmont Co. Emma E. Laughlin.

1519. **Scrophularia leporella** Bickn. Hare Figwort. Barnesville, Belmont Co. Emma E. Laughlin.

1525.1. **Pentstemon grandiflorus** Nutt. Large-flowered Beard-tongue. Miami valley, near Miami, Hamilton Co. Collector, Louise G. Phillips. Specimen in the University of Cincinnati herbarium. Reported by E. Lucy Braun.

1565. **Antirrhinum majus** L. Great Snapdragon. An escape from cultivation. Hillsboro, Highland Co. Katie M. Roads.

1568. **Chaenorrhinum minus** (L.) Lange. Lesser Toadflax. Barnesville, Belmont Co. Emma E. Laughlin.

1571. **Cymbalaria cymbalaria** (L.) Wettst. Kenilworth Ivy. Hillsboro, Highland Co. Katie M. Roads.

1594.1. **Amsinckia lycopsioides** Lehm. Amsinckia. Adventive from California. Barnesville, Belmont Co. Emma E. Laughlin.

1595.1. **Myosotis scorpioides** L. True Forget-me-not. Escaped from cultivation. Hillsboro, Highland Co. Kati M. Roads.

1614. **Lippia lanceolata** Mx. Frog-fruit. Wills Creek, Kimbolton, Guernsey Co. Emma E. Laughlin.

1616.1. **Ajuga genevensis** L. Erect Bugle-weed. From Europe. Eden Park, Cincinnati, Hamilton Co. E. Lucy Braun.

1682. **Monarda didyma** L. American Beebalm. Hillsboro, Highland Co. Katie M. Roads.

1687. **Salvia lancifolia** Poir. Lanceleaf Sage. Barnesville, Belmont Co. Emma E. Laughlin.

1689. **Salvia officinalis** L. Common Sage. Hillsboro, Highland Co. Katie M. Roads.

1689.1. **Salvia splendens** Ker-Gawl. Scarlet Sage. Escaped from cultivation along an alley. Hillsboro, Highland Co. Katie M. Roads.

1725.1. **Apium graveolens** L. Celery. Persistent after cultivation. Hillsboro, Highland Co. Katie M. Roads.

1726. **Apium petroselinum** L. Parsley. Hillsboro, Highland Co. Katie M. Roads.
1759. **Spermacoce glabra** Mx. Smooth Buttonweed. Sevenmile, Hamilton Co. E. Lucy Braun.
1760. **Diodia teres** Walt. Rough Buttonweed. East Cleveland, Cuyahoga Co. Edo Claassen.
1795. **Lonicera sempervirens** L. Trumpet Honeysuckle. Escaped from cultivation. Hillsboro, Highland Co. Katie M. Roads.
1836a. **Rudbeckia laciniata** L. (Double form). Goldenglow. Escaped from cultivation. Hillsboro, Highland Co. Katie M. Roads.
1839. **Echinacea purpurea** (L.) Moench. Purple Cone-flower. Claysville, Guernsey Co. Emma E. Laughlin.
1843. **Helianthus maximiliani** Schrad. Maximilian's Sunflower. Madeira, Hamilton Co. E. Lucy Braun.
1856. **Helianthus petiolaris** Nutt. Prairie Sunflower. Barnesvilla, Belmont Co. Emma E. Laughlin.
1874.1. **Cosmos bipinnatus** Cav. Cosmos. Persistent after cultivation. Hillsboro, Highland Co. Katie M. Roads.
1887.1. **Tagetes erecta** L. Common Marigold. Escaped from cultivation. Hillsboro, Highland Co. Katie M. Roads.
1901. **Grindelia squarrosa** (Pursh.) Dun. Broad-leaf Gumplant. Zanesville, Muskingum Co. E. V. Walker.
1994. **Chrysanthemum parthenium** (L.) Pers. Common Feverfew. Hillsboro, Highland Co. Katie M. Roads.
2063. **Hieracium aurantiacum** L. Orange Hawkweed. Barnesvills, Belmont Co. Emma E. Laughlin.
2064. **Crepis capillaris** (L.) Wallr. Smooth Hawksbeard. Barnesville, Belmont Co. Emma E. Laughlin.

ASCLEPIADORA VIRIDIS IN OHIO.

Robert F. Griggs.

While collecting spiders on the upland in the vicinity of Cantwell Cliff, in Hocking County, Ohio, Mr. W. M. Barrows noticed a peculiar appearing milkweed which he brought in to camp and turned over to the writer. Upon examination it proves to be *Asclepiadora viridis* (Walt) A. Gr. This is a southern plant listed as occurring from "Illinois to Kansas, Texas, South Carolina and Florida." It will be observed that the distribution as given is somewhat unusual, for most plants occurring both in Illinois and South Carolina also range further north in the east as well as across the southern states, following more or less typically Merriam's Carolinian area. The uplands on which it occurred have been found to harbor numerous other southern plants not known to occur within more than a hundred miles of the Sugar Grove area of which the present station is a part. Notable among these are *Viola hirsutula*, *Eupatorium rotundifolium* and *Eupatoriun aromaticun*, which are abundant in some stations on the upland. The fact that only a single plant of *Asclepiadora* was found might be taken to indicate that it has been introduced in cultural operations, but when the habits of the milkweeds are taken into account it is seen that its solitary occurrence does not necessarily throw doubt on its nativity for several of the rarer milkweeds in our area (*Asclepias Sullivantii*, *A. amplexicaulis* and *A. variegata*) have been found only once or twice, although the district has been collected over rather thoroughly for a number of years. While there is not, therefore, sufficient basis for a positive assertion that the plant is native, that appears to be a more likely hypothesis, than that it is introduced. If this is to be accepted as the most likely supposition, its occurrence in the Sugar Grove area is a rather notable extension of its range.

Date of Publication, March 29, 1919.

REPORT OF THE TWENTY-EIGHTH ANNUAL MEETING OF THE OHIO ACADEMY OF SCIENCE.

The Twenty-eighth Annual Meeting of the Ohio Academy of Science was held at Ohio State University, Columbus, Ohio, May 30 to June 1, 1918, under the presidency of Professor Francis L. Landacre. Forty-seven members were registered as in attendance; ten new members were elected.

After adjournment of the formal sessions, the botanists and zoologists went on an automobile excursion to the picturesque and ecologically interesting Sugar Grove region, and the geologists took a longer trip for the study of the rock series (Niagara to Carboniferous) and topography between Hillsboro and the Scioto River.

General Program

Thursday, May 30.

10:30 A. M.—Business Meeting.
12:30 P. M.—Luncheon.
2:00 P. M.—Reading of Papers, General Session.
4:00 P. M.—Demonstrations.
6:00 P. M.—Dinner, followed by Address of the President, Professor Francis L. Landacre, Ohio State University, "The Origin of the Cerebral Ganglia of the Vertebrates."

Friday, May 31.

9:00 A. M.—Reading of Papers, Sectional Session.
12:30 P. M.—Luncheon.
2:00 P. M.—Adjourned Business Meeting.
3:00 P. M.—Reading of Papers, Sectional Session.
6:00 P. M.—Supper.

7:30 P. M.—Symposium: "Science and the War"—

"The Work of the Ground Schools in the Training of the Air Forces of the United States," Professor F. C. Blake.

"Modern Methods of Plant Disease Control," Professor W. G. Stover.

"Psychological Tests in the Army," Captain George F. Arps.

"Methods of Teaching the Theory of Flight in Schools of Aeronautics," Professor H. C. Lord.

"Topography and the War on the Western Front," Professor T. M. Hills.

"The Newer Demands on Physics and Physics Teachers Due to the War," Professor E. H. Johnson.

SATURDAY, JUNE 1.

Excursions.

MINUTES OF BUSINESS MEETINGS

The first business session was called to order by President Landacre at 10:30 A. M., on Thursday, May 30. An adjourned session was held at 2:00 P. M. on the following day.

The appointment of the following committees for the meeting was announced by the chair:

Committee on Membership—R. C. Osburn, F. C. Blake, R. J. Seymour.

Committee on Resolutions—M. M. Metcalf.

Committee on Necrology—A. M. Bleile.

The following Auditing Committee was elected by the Academy: F. C. Blake, E. N. Transeau.

The following Nominating Committee was elected by the ballot of the Academy: T. C. Mendenhall, L. G. Westgate, F. L. Landacre.

Report of the Secretary

The following report by the Secretary was received and ordered filed:

DELAWARE, OHIO, May 29, 1918.

To the Ohio Academy of Science:

The work of the Secretary has consisted largely in the usual routine correspondence and in the carrying out of the directions of the Executive Committee, as noted in the report of that committee.

The report of the Twenty-seventh Annual Meeting was prepared rather unusually promptly and forwarded to *Science*. Its fate is shown by the following quotation from a letter by Professor Cattell, Editor of *Science*, under date of August 30:

"Owing to a necessary reduction in the size of the journal, it has been very much overcrowded this year and it has seemed impossible to find space for the report. I hope that the reduction in the size of *Science* is only temporary and that you will be so kind as to send me the report of next year's meeting."

The report will be prepared in case its publication is assured.

Notices of the Twenty-eighth Annual Meeting have been sent to the leading Columbus dailies with a request for publicity; but it has seemed hardly worth while to send such notices to Cleveland, Cincinnati and Toledo papers, as in the past. If the Academy so desires, notices will next year be sent to the larger list of papers.

A number of officers and committee members have this year been prevented from carrying out their work for the Academy. Professor Lamb has been compelled by ill health to give up the Vice-presidency for Geology, and Professor Westgate has been acting in his place. Professor Carney's new duties have taken him away from the State so much of the time that it has been impossible for him to serve with either the Executive Committee or the Committee on Codification of the Constitution. The Secretary has also received word from Professor Waite of his appointment as Captain in the Surgeon General's office and his inability to take any active part in the work of the Editorial Board of the Ohio Journal of Science. And at the last moment a letter from Professor Samuel R. Williams announces that he will be prevented from attending the meeting because of serious illness in his household; Professor Moore will be present to serve in his stead.

The members of the Academy may be interested in two rather conspicuous, but perhaps unconscious, changes in policy regarding the meeting place. During the decade, 1891-1900, all but two meetings were held in Columbus; during the next decade only three meetings were held in Columbus; since 1900 seven of the eight meetings (including the present session) have been held in Columbus. Since 1913 no invitation has been received except the cordial and generous standing invitation from the State University. There can hardly be a question that Columbus is the most generally convenient and desirable place for the meetings of the Academy. On the other hand, it may be worth careful consideration whether an occasional meeting in some other city does not aid in stimulating interest in the Academy throughout the State.

Finally the Secretary wishes to raise another question of policy. Is it not time for the Academy to establish a permanent headquarters in Columbus, to which all Academy mail may go, and from which all Academy business may be transacted? If the time is not ripe for this action, the Secretary would recommend, at least, that the new secretary be elected from Columbus, to facilitate closer co-operation with the Treasurer and with Mr. Reeder of the Library. Partly for this reason, and partly for personal reasons, the present secretary would request the Nominating Committee to omit his name from the list of nominations to be presented at the second business session of this meeting.

Respectfully submitted,

EDWARD L. RICE, *Secretary.*

The recommendations of the Secretary relative to place of meeting and establishment of a permanent Academy headquarters were referred to a special committee for consideration and report to the Academy. The committee reported as follows:

1. With reference to the place of meeting, the committee is of the opinion that the present practice of the Academy, of meeting as a general thing in Columbus, but leaving the way open to meet at other places in the State when occasion offers, should be continued.

2. With reference to the establishment of a permanent headquarters for the Academy at Columbus, from which all Academy business may be transacted, the committee has no recommendation to offer.

Respectfully submitted,

Stephen R. Williams,
L. G. Westgate,
C. G. Shatzer.

Report of the Treasurer for the Year 1917-18

The report of the Treasurer was received as follows, and referred to the Auditing Committee, whose report is appended.

For the year since our last annual meeting, the receipts including balance from last year, have amounted to $474.20, and the expenditures to $272.85, leaving a cash balance of $201.35.

RECEIPTS

Balance from last year	$139.10
For sale of publications	32.10
Membership dues	303.00
	$474.20

EXPENSES

Miscellaneous expenses	$ 70.85
202 subscriptions to the Ohio Journal of Science	202.00
Balance, May 30, 1918	201.35
	$474.20

Respectfully submitted,

Jas. S. Hine, *Treasurer.*

May 30, 1918.

The Auditing Committee has verified the receipts and expenditures of the Treasurer of the Academy, Professor J. S. Hine, and finds that they are correct.

E. N. Transeau,
F. C. Blake.

Report of the Executive Committee

The report of the Executive Committee was received as follows and ordered filed.

DELAWARE, OHIO, May 27, 1918.

To the Ohio Academy of Science:

A single meeting of the Executive Committee has been held since the last Annual Meeting—on December 8, 1917. Professors Landacre, Hine, Shatzer and Rice were in attendance. Following the custom of the last few years, all officers and chairmen of standing committees were invited to meet with the Executive Committee, Vice-Presidents Detmers and Seymour responded to this invitation.

The place and date of the Annual Meeting were determined; and the Program Committee was requested to arrange, if possible, for field trips on Saturday, June 1, and to give an increased prominence to the item of demonstrations in the program for the meeting. Both suggestions have borne fruit. It is now left for the Academy to prove the fruit in the eating.

There was some discussion of the propriety of the Academy paying the travelling expenses of the members of the Executive Committee in attending meetings and the clerical, printing and postage bills incurred by members of the Program Committee in arranging the program. The Executive Committee was not ready to make any formal recommendation in this matter.

The Secretary was authorized to have a set of the Annual Reports of the Academy bound for the use of present and future secretaries. (Steps have been taken by the Secretary, in conference with Mr. Reeder, to carry out this action.)

The Secretary was instructed to take up with Mr. Reeder the matter of exchanges with the Marine Biological Laboratory, Woods Hole, Mass., and to secure, if practicable, the placing of a complete set of the Proceedings in the Library of the Laboratory. (Consultation with Mr. Reeder showed that the Academy had expressed its willingness to supply the Laboratory with lacking numbers of the Academy publications, but that no reply had been received).

The Secretary was also instructed to renew correspondence looking toward the establishment of a Section for Psychology in the Academy. (A questionnaire concerning the desirability of this section was mailed to a number of the leading psychologists of the State; the consensus of opinion was strongly in favor of the establishment of the section, but equally strongly against attempting this action at this time, when the psychologists are so generally in national service).

In view of the action of the last Annual Meeting, looking toward amendment, the Executive Committee has postponed the re-printing of the Constitution and By-Laws ordered by the Academy.

The question was raised by several members of the Academy whether war conditions made it desirable to omit this year's Annual Meeting. This question was carefully considered by the Executive Committee by correspondence. The practically unanimous decision was that the demand of patriotism was for holding the meeting rather than for omitting it, even if the attendance might be materially decreased.

An invitation was received by the Ohio Academy to send a delegate to the Semi-Centennial Anniversary of the Kansas Academy of Science, celebrated on March 15 and 16. After consultation by mail, the Executive Committee directed the Secretary to communicate our congratulations to the Kansas Academy and to request Professor G. E. Coghill, of the University of Kansas, a member of the Ohio Academy from 1907 to 1915, to act as our representative. (This was done by night letters, under date of March 13).

Respectfully submitted,

EDWARD L. RICE,
Secretary for the Committee.

Report of the Publication Committee

No report of the Publication Committee was presented.

Report of the Trustees of the Emerson McMillin Research Fund.

The following report of the Trustees of the Research Fund was received and referred to the Auditing Committee, whose report is appended.

May 30, 1918.

RECEIPTS			
Balance April 1, 1917		$778.64	
March 15, 1918, from Mr. McMillin		250.00	
			$1,028.64
EXPENDITURES.			
For Research:			
Geo. D. Hubbard		$ 22.32	
E. L. Rice		55.40	
L. B. Walton		37.40	
			115.12
Balance in Bank			$ 913.52
GRANTS.			
L. B. Walton	$ 75.00		
E. N. Transeau	75.00		
E. L. Rice	55.40		
H. W. Lutz	25.00		
		$ 230.40	
Paid on above grants		92.80	
Liability on grants			$ 137.60
Net assets			$ 775.92

HERBERT OSBORN,
T. C. MENDENHALL.

May 30, 1918, audited and found correct.

E. N. TRANSEAU,
T. C. BLAKE,
Auditing Committee.

In addition to the financial report for the year, the Trustees presented the following announcement concerning the use of the McMillin Research Fund, which was approved by the Academy.

The McMillin Research Fund of the Ohio Academy of Science has been maintained through the generosity of Emerson McMillin and grants from this fund are made upon application to the Trustees of the fund.

Applications for grants should include a statement of the subject to be investigated, the nature of the expenses to be covered and in so far as practicable a list of the proposed items of expense in such manner that the Trustees may determine the expenses and the allowance needed.

In rendering accounts it is desirable that an itemized statement be submitted, showing the cost of apparatus or supplies used, or, in case of traveling expenses, the localities visited, amounts of railroad fare, hotel and other expenses as incurred. Payments granted from this fund will, as a rule, be made only after the expenses have been incurred and upon receipt of detailed statement. Original vouchers should be furnished when possible.

Apparatus, books, maps or material supplies not consumed during the investigation, which may be secured with grants from this fund are to be the property of the Academy and after the investigation is completed should be accounted for to the Trustees or deposited with such officer of the Academy as the Trustees may direct.

It is expected that the results of such investigations will be published and if other means of publication are not available, the Trustees will try to assist in securing suitable publication.

T. C. MENDENHALL, *Chairman.*

The Trustees further reported to the Academy a proposal to invest five hundred dollars of the Research Fund in Liberty Bonds, subject to the approval of Mr. McMillin. The Academy voted its hearty endorsement of this proposal.

Report of the Library Committee

For the Library Committee, Mr. Reeder, of the Ohio State University Library, presented the following report, which was received and ordered filed.

May 30, 1918.

To the Ohio Academy of Science:

At the last meeting of the Academy, it was voted to turn over to the University Library for incorporation in its collection, the materials received through exchanges by the Academy. In accordance with this action, the work of the year has been the unifying of these files. A sheet record has been made of the collections of the Academy as they stood at the time of transfer. As opportunity presented, the University Library has taken these sets and checked them. If needed in the Library, these sets, or individual items, have been added; if not needed, the material has been added to the duplicate collections for exchange purposes. In case any binding has been done, the volumes have been marked with the special book-plate which the Academy authorized at its last meeting. If it had not been for the absence of the Librarian on war work, this process of incorporation would have been completed by this date, but a portion of it will have to go over into this coming year.

In connection with the general policy of increasing exchanges, the University Library has been able to add new names to the list of the Academy. The combination of the Ohio Journal of Science, the Bulletins of the Ohio Biological Survey and the Proceedings of the Ohio Academy of Science makes a series of sets that command attention and of sufficient value to give a good basis for arranging terms of exchange. During the year several libraries and societies have completed their sets of the Special Papers and Annual Reports of the Academy on an exchange basis.

The only publication issued by the Academy during the year was the Annual Report of the Twenty-seventh Meeting, April 6 and 7, 1917. This report was mailed to the membership list as printed in that report and to all exchanges on the list.

The sale of publications during the year amounted to $24.35. This sum has been turned over to the Treasurer.

In accordance with the recommendation of the Executive Committee, a complete set of Annual Reports Nos. 1–25, have been bound for use of the Secretary.

At the last meeting of the Academy the Committee on Catalog of Scientific Journals was discharged and the work turned over to the Library Committee. This proposition stands today about in the same situation as at the time of the last report, with two exceptions: (1) Oberlin College has added about 3,000 cards to the Catalog during the year; and (2) the Catalog itself has been placed in order and now occupies ten (10) trays in the catalog in the University Library.

C. W. Reeder.

Report of the Committee on Legislation

The following report of the Committee on Legislation, presented by the chairman, Dr. Mendenhall, was received and ordered filed.

In presenting what may be considered as a preliminary report or what may be considered as a report of progress your committee regrets to say that circumstances have made it impracticable to meet for thorough discussion of the questions that might arise and that therefore the suggestions offered must be considered as tentative and that suggestions or instructions along any of the lines mentioned will be welcomed. Since there is not likely to be another meeting of the Academy before the next Assembly meets, some direction or indication of the wishes of the Academy will be of special value.

There has been no session of the Assembly since our last meeting and therefore no presentation of our wishes has been possible.

It appears to the committee that desired legislation may be sought along two lines; first, to provide funds for the Academy to undertake definite researches along special lines and to provide a fund for the publication of the proceedings of the society; second, to secure such legislation as may connect the Academy in an advisory capacity with the State in regard to matters of scientific importance requiring technical scientific information, and which the membership of the Academy is qualified to give.

For the first purpose it seems that the most probable fund might be one providing for publication either directly by state printing, with perhaps, a limitation of say 500 pages per year or a direct appropriation, to be expended by the Society for publication purposes. Such a request might be the first to urge, and then a request for the appropriation of a research fund, to be expended under the direction of the Trustees of the Research Fund of the Academy in such an amount as might be deemed essential for the investigations proposed.

For the second general purpose, there would seem to be necessary an act creating an advisory committee within the Academy, with power to form sub-committees for specific problems, especially with reference to needed legislation along lines within the scope of the Academy. Such, for example, as legislation concerning conservation and utilization of natural resources of the state, the protection of forests, the development of fisheries, game and other natural resources, the best development and utilization of which are matters of scientific knowledge and which are in considerable degree now the subject of controversy by special interests, rather than the objects of care by intelligent agencies interested in their widest service and perpetuation.

Unless it is possible to have a careful discussion of these questions and to give certain fairly definite instructions, it would seem necessary in order to make any progress within the next year that the committee, or a new committee formed for the purpose, be given considerable discretion in the matter of character and extent of the legislation sought. While there is perhaps less hope at present on account of the urgency of other matters, it would seem that the importance of these measures for the Academy merit as prompt action as possible and it will be well certainly to have our needs formulated in such definite shape that we may be prepared to act as promptly as circumstances will permit.

T. C. Mendenhall, *Chairman*,
Herbert Osborn.

Owing to the request of Dr. Mendenhall to be excused from the chairmanship of the committee and to Prof. Waite's temporary absence on war work, it was voted that the present committee be discharged and that a new committee of five be appointed. The President appointed the following: Herbert Osborn, Chairman; T. C. Mendenhall, M. M. Metcalf, E. L. Rice, L. B. Walton.

Report of the Committee on Codification of the Constitution

The following report of the Committee on Codification of the Constitution, presented by Prof. Blake, was discussed at some length in both business sessions and finally laid upon the table by vote of the Academy.

May 30, 1918.

To the Ohio Academy of Science:

Two matters were referred to this committee—the codification of the Constitution and By-Laws and the question of lengthening the term of office of the President and Secretary. The term of office of the Treasurer was not specifically mentioned, but should be logically included with the others.

One member of the committee, Professor Carney, has been out of the State so much of the time that he has been practically unavailable; the remaining members, neither of whom was able to attend the last annual meeting, are somewhat in doubt concerning the intention of the Academy as to "codification," and are in decided disagreement concerning the question of the term of office.

Interpreting "codification" in the narrow sense, and not as the equivalent of general revision, the committee begs to report that the Secretary has a record of all amendments which have been passed, and that the preparation of the Constitution and By-Laws for the press will be a simple clerical matter when the Executive Committee is ready to proceed with the printing.

Considering the term of office of President, Secretary and Treasurer, the committee, while unable to present a definite recommendation, offers the following suggestions:

1. *Term of Office of President.*—One member of the committee favors the lengthening of the term to three years, for the following reasons: The Ohio Academy bears the same relation to the State Government that the National Academy of Science does to the Federal Government. For the period of the war and especially for the reconstruction period after the war it would seem that longer terms of office than at present would give the opportunity for some real constructive work of immense and permanent value. The other member feels that it is wiser to retain the present one year term, particularly in view of the fact that the President is expected to present the annual address. The change to the longer term would necessitate the preparation of three consecutive addresses by the same man would leave the Academy without a presidential address in two out of every three years. A third alternative would be the abolition of the address—a result equally objectionable with the others.

2. *Term of Office of Secretary.*—It is agreed by the committee that the office of the secretary should be somewhat permanent; and one member of the committee would secure this result through lengthening the term to five years. In favor of this view, he further suggests that the office of secretary should be the most permanent of any of the offices. If the presidency had a three year period and the secretaryship a five year period, it would seldom occur that both incumbents would complete their terms simultaneously. The important thing of the whole matter is continuity of constructive policy. The other member of the committee, (owing to the constitution of the committee, it is fair to Professor Blake to add that this member is the present secretary), believes that the desired permanency can be secured by indefinite re-election, while the Academy may more easily and more speedily eliminate an undesirable official.

3. *Term of Office of Treasurer.*—The arguments pro and con are essentially as in the case of the secretaryship.

Respectfully submitted,

Edward L. Rice,
Frederick C. Blake,
Committee.

Election of Officers

From the double slate of nominations prepared by the Nominating Committee, the following officers for 1918-19 were elected by the ballot of the Academy.

President—Professor M. M. Metcalf, Oberlin College, Oberlin.

Vice-President for Zoology—Professor R. A. Budington, Oberlin College, Oberlin.

Vice-President for Botany—Professor C. E. O'Neal, Ohio Wesleyan University, Delaware.

Vice-President for Geology—Professor G. F. Lamb, Mt. Union College, Alliance.

Vice-President for Physics—Professor Samuel R. Williams, Oberlin College, Oberlin. (On resignation of Prof. Williams, owing to absence from the State on leave, the Executive Committee appointed Professor S. J. M. Allen, University of Cincinnati, to fill vacancy).

Vice-President for Medical Sciences—Professor Ernest Scott, Ohio State University, Columbus.

Secretary—Professor E. L. Rice, Ohio Wesleyan University, Delaware.

Treasurer—Professor J. S. Hine, Ohio State University, Columbus.

Elective Members of Executive Committee—Professor R. C. Osburn, Ohio State University, Columbus; Professor L. B. Walton, Kenyon College, Gambier.

Member of Publication Committee—Professor L. G. Westgate, Ohio Wesleyan University, Delaware.

Trustees of Research Fund—(For three years). Dr. T. C. MENDENHALL, Ravenna; (For one year, to fill vacancy) Professor M. E. STICKNEY, Denison University, Granville.

Member of Library Committee—Professor W. C. MILLS, Ohio State University, Columbus.

Also, on nomination by the Nominating Committee, the following were elected to represent the Academy on the editorial board of the Ohio Journal of Science:

Zoology—Professor R. A. BUDINGTON, Oberlin College, Oberlin.

Botany—Professor M. E. STICKNEY, Denison University, Granville.

Geology—Professor G. D. HUBBARD, Oberlin College, Oberlin.

Physics—Professor S. J. M. ALLEN, University of Cincinnati, Cincinnati.

Anatomy, Physiology, etc.—Professor W. F. MERCER, Ohio University, Athens.

Election of Members

The Membership Committee reported ten names for election to membership; one additional name, previously approved by the Executive Committee and marked with * in the following list, was presented for ratification. All were elected as follows.

Basinger, Almon J., Entomology, Zoology, Botany, Columbiana.
*Gullum, Frank B., Chemistry, Physics, 237 E. Northwood Ave., Columbus.
Herrick, Francis H., Animal Behavior, Life and Instincts of Birds, Western Reserve University, Cleveland.
Lowry, Phil R., Entomology and Zoology, 1597 Hunter Ave., Columbus.
Mitchell, Roger I., Entomology, Sta. E, Route 6, Columbus.
Parks, F. H., Entomology, Botany and Zoology Bldg., Ohio State University, Columbus.
Sampson, Homer C., Botany, Ohio State University, Columbus.
Spohr, Carl F., Medical Dept., Ohio State University, Columbus.
Tucker, W. M., Geology, Dept. of Geology, Ohio State University, Columbus.
Waller, A. E., Botany, Agronomy, Dept. of Botany, Ohio State University, Columbus.
Wickliff, E. L., Zoology, Ornithology, Columbus.

The Report of the Committee on Necrology

The following report was presented by the Committee on Necrology.

ADOLPH FEIEL.

Born in Wurtemberg in June, 1836; died in Columbus, February 22, 1917.

He received a common school education at home and came to the United States when eighteen years old. From 1876 to 1879 he was a student in Starling Medical College, completing the regular course in medicine—then three years—but refused to apply for a degree, stating in his modest way that he did not feel himself worthy of the honor.

He was appointed assistant and later given charge of the course in Histology in Starling Medical College. In 1895 he came to the Ohio State University as instructor in Histology, which position he held until shortly before his death.

He was remarkably proficient in histological technique. His interpretation of a microscopic preparation was exceeded by no one I ever knew. His study and knowledge of the protozoa was extensive.

His induction into science was interesting. A guest at a hotel where Mr. Feiel was them employed left behind a popular book on science. In it was an illustrated description of the human skin. With characteristic conservation, our friend doubted that so much detail was present in such an apparently simple object. His savings went toward the purchase of a microscope, and then came a realization of the difficulties that beset the investigator. He entered Starling College mainly for the purpose of obtaining section of the human skin and while this was the beginning his scientific spirit led him on and on in the pursuit of knowledge in his chosen field.

He was a man of sterling integrity and of honest ideals. He was joint author of two papers published in the transactions of the American Microscopial Society dealing with "The Trophic Effects upon the Heart after Section of the Vagi."

A. M. Bleile.

Resolutions

The following resolutions were presented by the Committee on Resolutions and adopted by the Academy.

1. The Academy wishes to express its grateful appreciation of the hospitality of the Ohio State University in connection with its meeting.

2. The Academy wishes again to express to Mr. Emerson McMillin its sense of the great service he is rendering in his generous gifts to the Research Fund, and its gratitude to him for his support of this, the vital part of our work.

M. M. Metcalf, *Com.*

The following additional resolution was adopted by the Academy on motion of Professor Walton.

The Ohio Academy of Science places itself on record as deprecating the suppression of the study of the German language in the curricula of some of our colleges.

The study of German should be continued not only by reason of its direct utility to our troops abroad, but also because it is fundamentally necessary to science and productive scholarship.

It is not the language, but Prussian ideas, which are antagonistic to the Allied nations; and any action which prevents the efficient development of scholarship and science, and of the industries dependent upon them, will prove advantageous to our enemies.

Proposed Restriction of Membership of Academy

A proposition was presented to the Academy by Dr. T. C. Mendenhall, looking to a restriction of membership to those engaged in professional and productive scientific work. Thus membership might be "made of greater importance by being made more difficult," and the Ohio Academy might realize more fully the "influence throughout the State that such a body should have." The Academy voted a general approval of the suggestion, together with its reference to a committee to be appointed by the President. This action and the report of the committee (to be included in the preliminary announcement of the next Annual Meeting) are to be interpreted as notice of a proposed amendment of the Constitution. The matter was referred by the President to the Executive Committee.

Miscellaneous Business

Voted that the Treasurer be authorized to pay the bill for binding a file of the Annual Reports, prepared by the Library Committee for the use of the Secretary.

Voted that the Secretary be authorized to draw upon the Treasurer for the payment of clerical assistance, not to exceed fifty dollars per year.

Adjournment

The meeting adjourned without determining the place of the next meeting.

Scientific Sessions

The complete scientific program of the meeting follows:

Presidential Address

"The Origin of the Cerebral Ganglia of the Vertebrates,"
F. L. Landacre

Symposium on Science and the War

The Work of the Ground Schools in the Training of the Air Forces of the United States.......F. C. Blake
Modern Methods of Plant Disease Control.......W. G. Stover
Psychological Tests in the Army.......George F. Arps
Methods of Teaching the Theory of Flight in Schools of Aeronautics..H. C. Lord
Topography and the War on the Western Front.......T. M. Hills
The Newer Demands on Physics and Physics Teachers Due to the War.......E. H. Johnson

Papers

1. Notes on Distribution of North Atlantic Bryoza. 10 min. (Lantern), Raymond C. Osburn
2. The Economic Value of the Ephemerida. 5 min.......Chas. P. Fox
3. A Peculiar Habit of the Rusty Grackle. 3 min.......Edward L. Rice
4. Remarks on Leaf Hoppers on Hawaiian Islands. 8 min....Herbert Osborn
5. The Fauna of a Series of Rock-bottomed Ponds. 15 min. (Lantern), F. H. Krecker
6. The Habits of the Folding-door Spiders. 20 min.......W. M. Barrows
7. The Subterranean Life of Meadows and Pastures. 10 min..Herbert Osborn
8. Opalina and the Origin of the Ciliata. 25 min.......Maynard M. Metcalf
9. The Bryozoan Gizzard. 3 min.......Raymond C. Osburn
10. Free-swimming Larval Colonies of Pectinatella from Black Channel, Cedar Point. 8 min.......Stephen R. Williams
11. Anatomy of Echinorhynchus sp. 8 min. C. F. McKhann, Jr., introduced by Stephen R. Williams
12. The Effect of Certain Ductless Gland Extracts on Plant Tissues. 10 min. (Lantern).......R. A. Budington
13. Our Knowledge of Ohio Crustacea. 5 min.......Raymond C. Osburn
14. A List of Ohio Spiders (now in press). 5 min.......W. M. Barrows
15. A Preliminary Survey of the Protozoa of Mirror Lake on the Ohio State University Campus. 6 min.......Mabel E. Stehle
16. Application of Colloid Chemistry to Nephritis. 15 min..Hazel C. Cameron
17. Reaction Time in the Blind and the Deaf. 5 min.......A. M. Bleile
18. The Effect of Radium Radiations on the Germ Cells of Drosophila ampelophila. 20 min.......W. M. Barrows
19. Studies of Vaso-motor Balance. 15 min. Clyde Brooks, Clayton McPeek and R. J. Seymour
20. Note on the Catalase Content of the Turtle Heart. 4 min....R. J. Seymour
21. Pneumococcus Types. 5 min.......Carl L. Spohr
22. The Cancer Problem. 20 min. (Lantern)....... Ernest Scott
23. Behavior of the X-chromosomes in Branchipus vernalis. 5 min. R. C. Baker
24. Work of the Plant Disease Survey, U. S. D. A. in Ohio. 10 min...A. D. Selby
25. The Lecidaeceæ of Ohio. 15 min. (Lantern).......Bruce Fink
26. Interesting Ascomycetes. 10 min. (Lantern).......Bruce Fink
27. A Revised Course for Secondary Botany. 15 min.......Blanche McAvoy
28. Succession on Prairies. 20 min. (Lantern).......Homer C. Sampson

29. Regeneration Studies of Bryophyllum. 20 min. (Lantern). Charles W. McIntyre
30. An Electric Drying Oven for Plant Presses. 5 min.......... E. Lucy Braun
31. Inland Associations of Algæ. 20 min. (Lantern)........ Edgar N. Transeau
32. The Effect of Hairy Coverings on Transpiration. 10 min. (Lantern). Jasper D. Sayre
33. The Indicator Significance of Plant Associations in Crop Distribution in the United States. 25 min. (Lantern)................ Adolph Waller
34. Vegetative Reproduction of the Pinnatifid Spleenwort. 5 min. (Lantern). Clara G. Mark
35. Effect of Seed Treatment for Smut on Germination. 10 min. Wilmer G. Stover
36. An Apple Root Fungous Disease. 10 min................ Harry W. Lutz
37. Characteristics of the Eruption of Katmai as Indicated by its Effect on Vegetation. 15 min. (Lantern).................... Robert F. Griggs
38. Some Land Forms of Central Southern Ohio. 10 min.... Lewis G. Westgate
39. Fossils of the Greenfield (Ohio) Dolomite and Where to Find Them. 15 min.. C. W. Napper
40. Moulding Sands of Ohio. 10 min...................... J. A. Bownocker
41. Effects of the Wisconsin Glacier on a Portion of the Whitewater Valley in Indiana. 15 min.................................... W. M. Tucker
42. Some Especially Interesting New Species of Richmond Fossils. 8 min. (Lantern)... W. H. Shideler
43. Effect of Transverse Magnetic Field on Some of the Physical Properties of Nickel Wire. 10 min................................ A. A. Atkinson
44. Title to be announced.................................. T. C. Mendenhall
45. The Magnetic-Mechanical Analysis of Cast Iron. 10 min. Samuel R. Williams

Demonstrations

1. Specimens and Photographs from the Valley of Ten Thousand Smokes. Robert F. Griggs
2. Specimen of a Dermoid Cyst with Teeth, loaned by Dr. H. Moore, Oxford.................................... Stephen R. Williams
3. Leaf Hoppers of Hawaiian Islands...................... Herbert Osborn
4. One-eyed Frog (Acris gryllus).......................... F. H. Krecker
5. Laboratory Table Tray.................. F. H. Krecker and W. J. Kostir
6. Colony Forms in Marine Bryozoa.................. Raymond C. Osburn
7. Exhibit of Greenfield (Ohio) Dolomite Fossils............... C. W. Napper
8. Two New Varieties of Acer rubrum...................... Freda Detmers
9. A Collection of Ohio Spiders; a Method of Exhibiting Spiders; Nest of Folding-door Spider.............................. W. M. Barrows
10. A Vaso-motor Balance..... Clyde Brooks, Clayton McPeek. R. J. Seymour
11. Models of Embryonic Skull of Eumeces.................. Edward L. Rice
12. Sections of Nasal Capsule and Olfactory Nerves of Embryonic Eumeces. Edward L. Rice
13. X-chromosomes of Branchipus vernalis...................... R. C. Baker
14. Origin of Cartilage from Ectoderm in the Urodeles......... F. L. Landacre

Edward L. Rice, *Secretary.*

1919 MEETING

of the

OHIO ACADEMY OF SCIENCE.

The Ohio Academy of Science will meet in Columbus, at the Ohio State University, on Thursday, Friday and Saturday, May 29, 30 and 31, 1919.

Detailed announcements regarding program, meeting places for the various sections and other local arrangements will be sent out by the Secretary.

IX. THE BEGINNINGS OF REVEGETATION IN KATMAI VALLEY.

ROBERT F. GRIGGS.

The effect of the great eruption of Mount Katmai in Alaska on plant life, and the remarkable recovery of vegetation around Kodiak have been discussed in previous papers of this series.[1] When it was observed with what rapidity the covering of ash at Kodiak was being removed by erosion, and that the new plant covering consisted almost entirely of old perennials which had survived and come up through the ash, it became evident that the main problem of revegetation must be worked out on the mainland, where the destruction of the antecedent vegetation was more complete, and the deposits in which the new plants must start very much deeper.

The present paper is published as a record of the first stages of the process in the valley of Katmai River, which, flowing under the Volcano in a narrow canyon, spreads out and for some twenty miles traverses a broad flat valley to the sea. (See map, page 319). These flats, in contrast to the steep mountains round about, contain considerable areas favorable to the study of revegetation.

METHODS OF WORK.

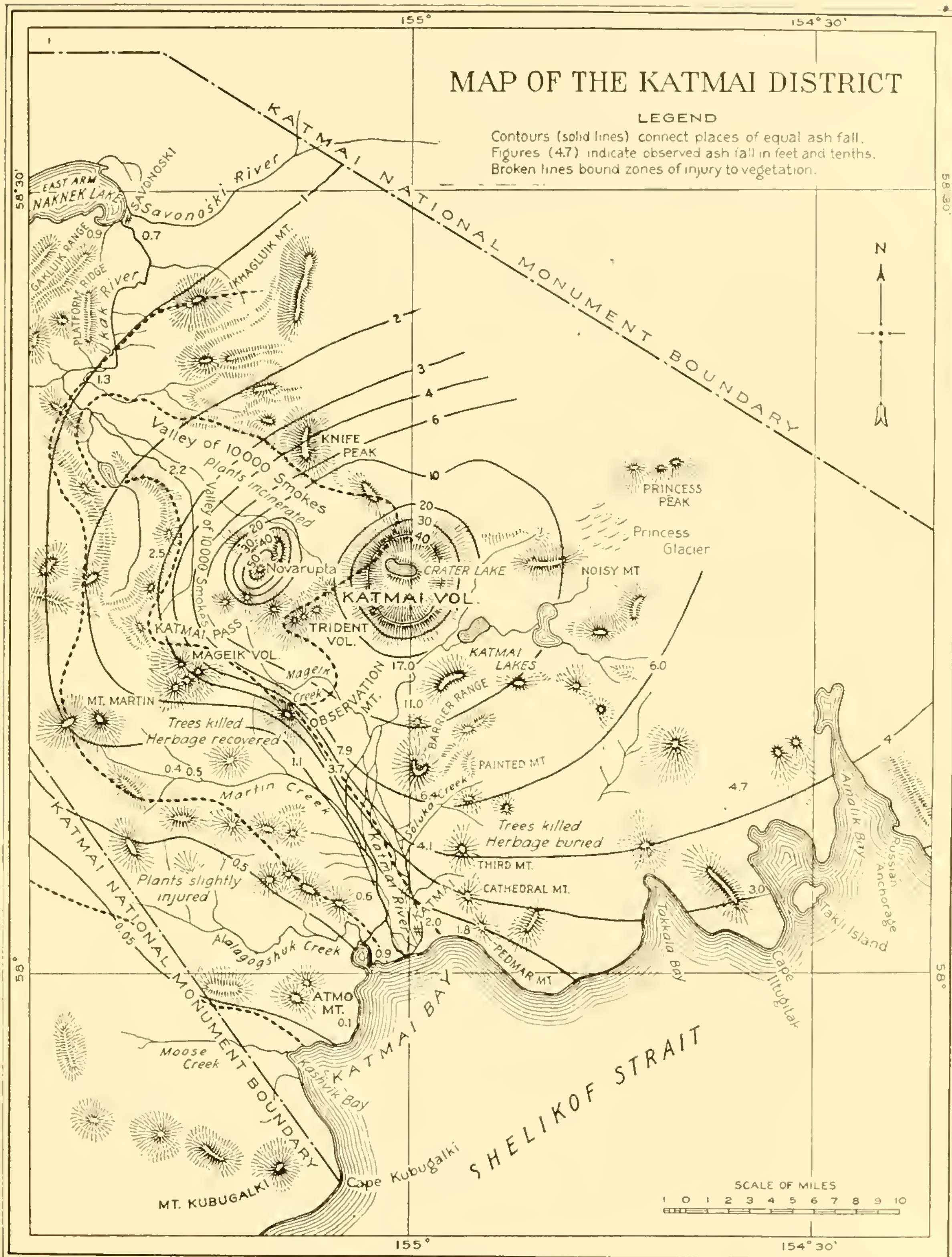
A considerable part of the work of the expeditions, which visited the country in 1915, 1916 and 1917, was the securing of records, both descriptive and photographic, of definite localities which may be visited at later dates and restudied for the purpose of recording the progress of returning vegetation.

[1]Griggs, R. F. Scientific Results of the Katmai Expeditions of the National Geographic Society.

I. The Recovery of Vegetation at Kodiak, Ohio Journal of Science 19: 1–57. 1918.

IV. The Character of the Eruption as Indicated by Its Effect on Nearby Vegetation. Ohio Journal of Science, 19: 173-209. 1919.

A full citation of literature is given in these papers, especially in I. General accounts of the expeditions have appeared in the National Geographic Magazine for January, 1917, and for February, 1918.


MAP OF THE KATMAI DISTRICT
LEGEND
Contours (solid lines) connect places of equal ash fall.
Figures (4.7) indicate observed ash fall in feet and tenths.
Broken lines bound zones of injury to vegetation.
155°
154° 30'
58° 30'
58°
N
KATMAI NATIONAL MONUMENT BOUNDARY
EAST ARM
NAKNEK LAKE
SAVONOSKI
Savonoski River
GAKLUIK RANGE
PLATFORM RIDGE
Ukak River
KHAGLUIK MT.
KNIFE PEAK
Valley of 10000 Smokes
Plants incinerated
Novarupta
CRATER LAKE
KATMAI VOL.
TRIDENT VOL.
KATMAI PASS
MAGEIK VOL.
Mageik Creek
OBSERVATION MT.
MT. MARTIN
Trees killed
Herbage recovered
Martin Creek
PRINCESS PEAK
Princess Glacier
NOISY MT
KATMAI LAKES
BARRIER RANGE
PAINTED MT
Soluka Creek
Trees killed
Herbage buried
THIRD MT.
CATHEDRAL MT.
Katmai River
Plants slightly injured
Alalagogshuk Creek
PEDMAR MT
Takhala Bay
Cape Iltugitak
Amalik Bay
Russian Anchorage
Takli Island
ATMO MT.
KATMAI BAY
Moose Creek
Kashvik Bay
SHELIKOF STRAIT
Cape Kubugalki
MT. KUBUGALKI
SCALE OF MILES
1 0 1 2 3 4 5 6 7 8 9 10

O E Williams

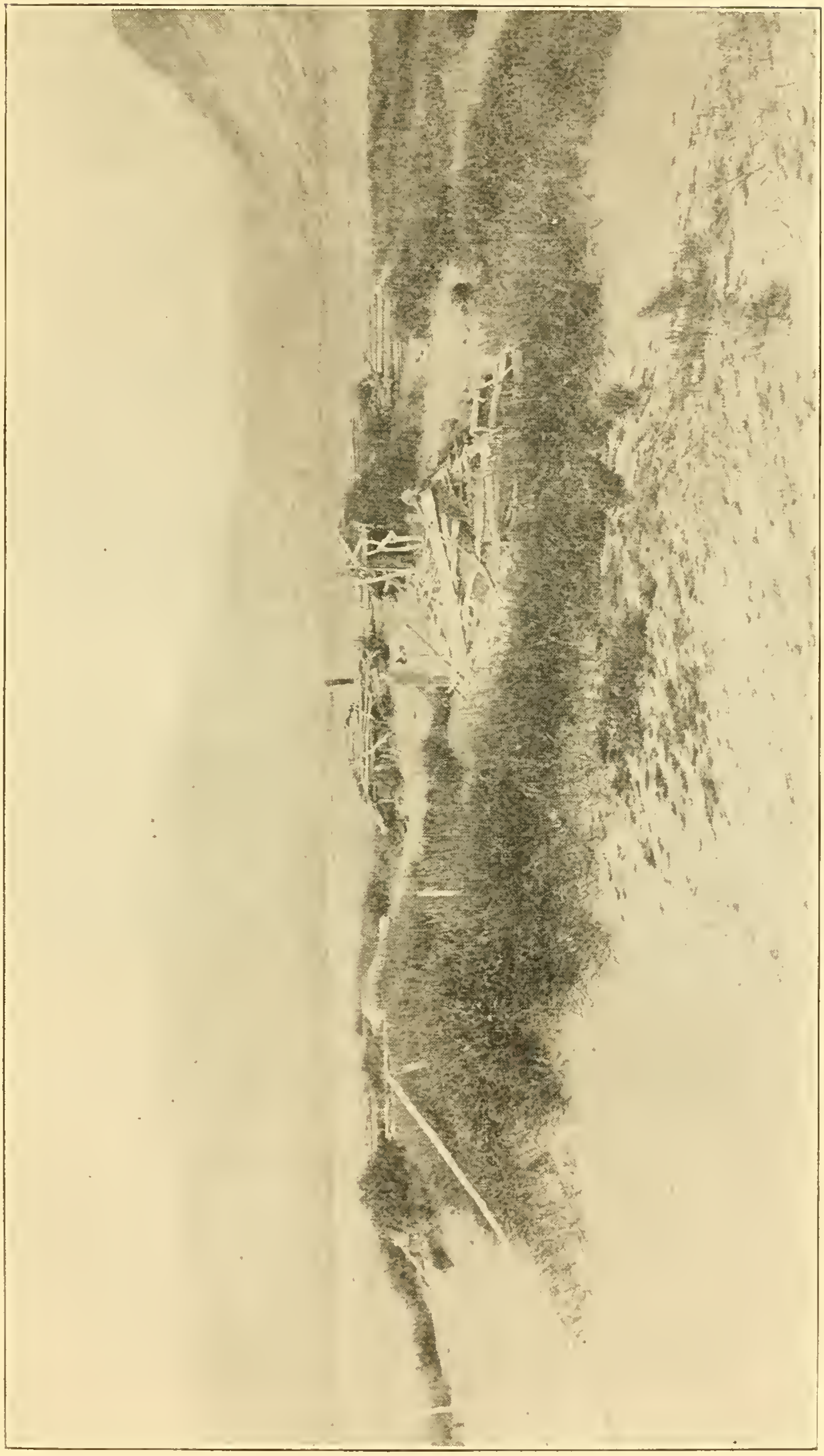
The effort has been to locate them in such a way that anyone can find them and carry on the study, if for any reason the writer should be prevented from continuing it.* Beside these formally established stations, there are many other localities, not susceptible of such precise location, which the writer expects to study repeatedly as opportunity presents. In the short time that has elapsed since the beginning of the work, changes at these stations for the most part have been small, so that the progress in revegetation here reported has been worked out from observation of the general conditions in the valley. But as time goes on, repeated records of conditions at the fixed stations and other localities photographed will furnish a more and more valuable record of progress, which finally will give us an understanding of the factors controlling the revegetation of volcanic deposits under the climatic conditions obtaining, and of the succession of plants in the process. Meanwhile, laboratory studies of plant growth in the ash have been made with samples brought back to the United States for the purpose. These, besides supplementing and aiding in the interpretation of the field observations, are of some interest in themselves.

CONDITION OF SURVIVALS.

The agents of revegetation consist of: (a) Surviving woody plants which protrude through the ash. (b) Herbage which has come up in places cleared of ash. (c) Seedlings starting in the deposits. The effects of the first two categories on the mainland may be dismissed with very brief discussion. The poplars, birches and alders have not recovered sufficiently to become of any consequence in revegetation, except as helping in places to maintain a windbreak under which new plants can start. None of them were found in fruit, although a few seedlings of poplar were observed in one place. But the larger willows, (*Salix alaxensis*, *Salix barclayi*, *Salix nuttallii*), have in places almost completely recovered and have begun to produce seed abundantly, which bids fair to become an important factor in revegetation.

The resurrected herbage, though of great interest as showing the possibilities possessed by plant life of surviving a violent eruption, is of minor importance in the revegetation of Katmai

*For a detailed discussion of the problems encountered in establishing the vegetation stations see the first paper of this series, pp. 24–31, on p. 174.



Photograph by D. B. Church

A PORTION OF KATMAI VILLAGE FOUR YEARS AFTER THE ERUPTION.
The increase in the vegetation is exclusively by vegetative extension. The present rate is about four feet per annum.

Valley. Although the oases, to be found in spots where conditions have permitted the recovery of the herbaceous plants, are conspicuous in the desert valley, their influence in the revegetation of the great bare areas is, from the nature of the case, quite limited. There are three ways in which they affect revegetation.

First, by direct extension out into the bare areas. Only two of the species present have sufficiently developed the power of sending out runners to be important in this respect.

Photograph by Robert F. Griggs

BEACH GRASS SENDING RUNNERS INTO BARE ASH.

Runners of the current season (1916) are sterile, but the shoots that came through in 1915 have fruited. The rate of extension is about four feet per annum.

The beach grass, (*Elymus arenarius*), is especially adapted to cope with shifting sand, and in many places in the vicinity of the shore it has been locally of great importance in renewing the plant cover. (See page 321.) Comparison of photographs taken in successive years and observation of the plants shows that the rate of extension is about four feet per annum.

The horsetail, (*Equisetum arvense*), was able to penetrate deposits so thick that nothing else could come through. Its capacity for penetration is most strikingly shown in the bottoms of numerous gullies washed in the ash areas where it was so deep that nothing could come through on the level. Observation of such places shows that it can penetrate deposits up to about three feet in thickness. The horsetail is not, however, of anything like the importance in Katmai Valley that it is at Kodiak.* The deposits are for the most part so thick that it is only here and there that even the horse tail could grow through them. (See picture.).

Second, the patches of surviving herbage serve as a wind break in the shelter of which new seedlings can start. This again is a function of considerable importance locally as will be seen from the discussion to follow.

Photograph by Robert F. Griggs

EQUISETUM COMING THROUGH IN THE BOTTOM OF A GULLEY WHERE THE DEPOSIT WAS TOO THICK FOR IT TO PENETRATE ELSEWHERE.

Third, the oases of resurrected vegetation furnish the seed which may be the basis for starting new vegetation in the desert round about. This, however, is not a factor of great consequence in this case. The plants have come back on the steep mountains, from which the ash quickly slid off, so much more freely than in the deeply buried valley that they would furnish abundant seed, even if nothing had survived on the flats. Most of the plants of the district have seed adapted

*See the first paper of this series, p. 43.

for wind distribution, and the wind is so efficient a factor in this region, (see page 339), that seed in abundance is transported great distances.

SEEDLINGS BEGINNING TO START.

The seedlings starting up to 1915 were so few, and occurred so sporadically, that in my report of operations that year I stated that revegetation had not yet begun and that the observations of that year could furnish no basis for a prediction as to when it would begin, but a definite change was noticeable in 1916.

Photograph by Robert F. Griggs

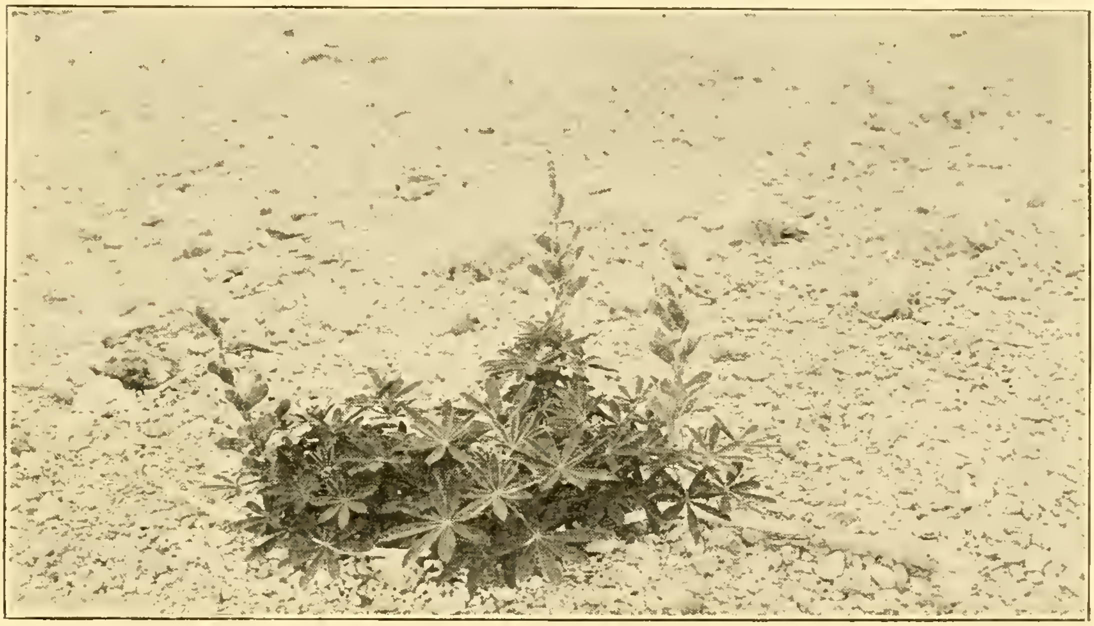
A GENERAL VIEW OF THE PUMICE PLAIN ON WHICH LUPINES WERE STARTING.

The dark spots right and left are lupines, like that shown close up on the opposite page. Although far apart they have grown thriftily.

The landscape was, to be sure, as bare as ever, but the careful observer could not fail to see in many habitats the definite, though slight, beginnings of new vegetation. These were most marked in the lower valley, and diminished as one approached the Volcano, but even in the upper valley large areas which were absolutely barren in 1915 were coming up with occasional lupine seedlings which, though so sparse and widely scattered that one had to search for them, were nevertheless thriving with every prospect that some of them would survive. Farther down the valley a few areas were found where similar seedlings had started in 1915 and, having persisted even in deep pumice deposits, were flowering and seeding abundantly in 1916; while in 1917 considerable areas as far up stream as Martin Creek were sparsely occupied by fruiting lupines, furnishing the basis for an increasing rate of revegetation.

LUPINES THE MOST EFFECTIVE PIONEERS.

While the new vegetation in the lower valley consists of many species of plants, in the more exposed places lupines are the only pioneers. (See pages 324 and 335). For this role they are well adapted, because of their large heavy seeds



Photograph by Robert F. Griggs

A LUPINE ON THE PUMICE FLAT AT MARTIN CREEK.
These plants first appeared in 1915. They were well provided with root tubercles and grew thriftily, fruiting freely in 1917. The soil is almost entirely without organic nitrogen.

which lodge where smaller seeds are blown away. On germination, moreover, their large supply of stored food enables them to grow into strong plants much more quickly than the other species present. But their capacity of utilizing atmospheric nitrogen through their root tubercles is probably the decisive factor, for the ash is almost devoid of nitrogenous compounds.[2] Lupines growing in pumice show an abundant development of root tubercles which must give their possessors enormous advantages over ordinary plants in the process of revegetation.

[2] Shipley, J. W. The Nitrogen Content of Katmai Ash. Paper No. V in this series, pages 213–223.

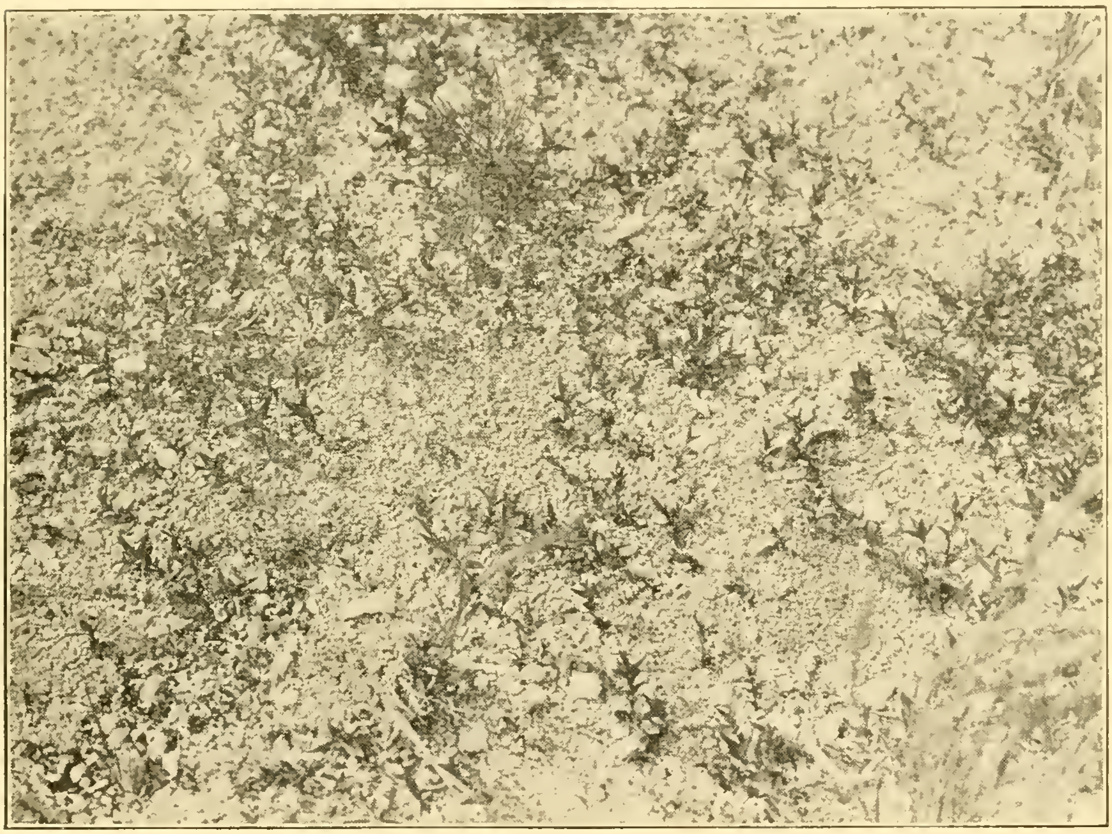
Photograph by D. B. Church

SEEDLINGS STARTING IN WATER-LAID ASH.

In outwash at the base of a hill where the ash was little contaminated with soil. Most of the abundant seedlings are grasses. (*Deschampsia* and *Calamagrostis*). The picture is not typical of conditions in Katmai Valley, but represents the extreme progress of revegetation, except in very wet places, up to 1916.

These lupines are, however, strictly confined to the valley and to situations that at one time or another have been overflowed by stream waters. On the surrounding hillsides and in other parts of the valley there are many areas that, to all appearance, offer quite as favorable habitats as those which are occupied by lupines, but not a single plant has ever been detected outside the flood plains except on oases of old soil.

The reason for this peculiarity of distribution is not clear at the present time. It may be that the seeds are water borne



Photograph by D. B. Church

SEEDLINGS OF EPILOBIUM ALASKÆ STARTING ON PUMICE IN A SPRINGY PLACE.

instead of wind disseminated. But the winds of the district are so extremely violent, (see below, page 339), as to make it appear unlikely that objects so slight as lupine seeds would resist their action. Legumes in general are known to be dependent on organisms in the soil for that innoculation with the tubercle bacteria upon which their success is dependent. It might well be that while these organisms were absent from the general mass of ash they were present in ash contaminated by flood waters.

Bacterial examinations of the soil in the neighborhood of the growing lupines, conducted by Jasper D. Sayre, have however failed to indicate the presence of the tubercle bacillus in the soil. The ash is extraordinarily poor in micro-organisms. Cultures from numerous collections made in 1917 remained altogether sterile, while in others a single organism developed consistently on some media. Otherwise no micro-organisms whatever were found, although the check samples of garden soil subjected to the same treatment fairly teemed with bacteria,

Photograph by Robert F. Griggs

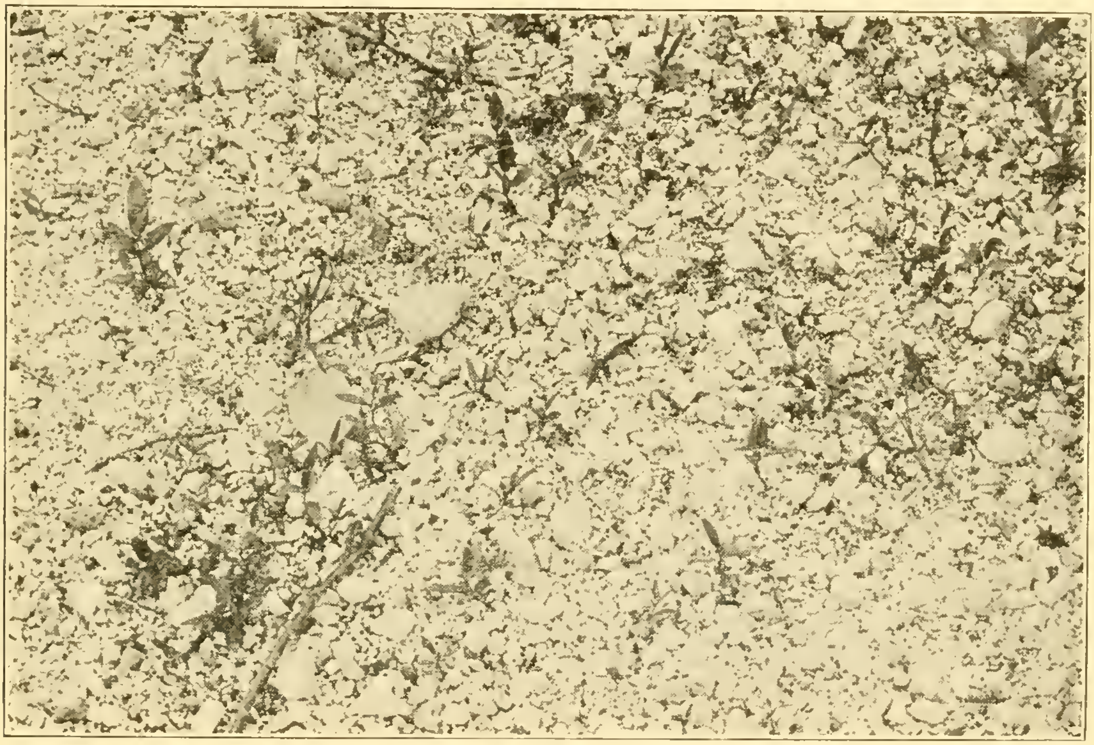
WILLOW SEEDLINGS COME UP IN FLOOD BORNE MUD IN KATMAI VALLEY. NATURAL SIZE.

indicating that there was nothing wrong with the methods of collecting and culturing the material.

The cultural work was interrupted at this stage by conditions incident to the war, but through the kindness of Dr. K. F. Kellerman, the Department of Agriculture undertook to investigate our suspicion that the one organism so consistently found was the tubercle bacillus. But when the report came it was negative. Our organism was pronounced not to be *Bacillus radicicola*. The matter must therefore be left in abeyance. But Mr. Sayre is continuing the bacterial work, having made further collections of soil for bacteriological study during the summer of 1918.

WILLOWS STARTING IN SOME PLACES.

In more sheltered situations, seedlings of a number of species are starting in many places. The most important of these are probably the grasses, *Deschampsia caespitosa* and *Calamagrostis langsdorfii*, (see page 326). With these are other herbaceous



Photograph by Robert F. Griggs

YEARLING WILLOW PLANTS GROWING IN WATER-LAID PUMICE.
The appearance of these plants in August, 1915, is shown on page 328.
This picture was taken in August, 1916.

species, including *Artemesia tilesii*, *Campe barbarea*, (see page 331), *Polemonium acutiflorum*, *Epilobium alaskæ*, (see page 327), *Mimulus langsdorfii* and also the frutescent *Sambucus pubens*. There are also considerable areas where the ground is covered with seedlings of willow, (*Salix alaxensis*, *Salix barclayi*, *Salix nuttallii* and *Salix bebbiana*). (See page 328). Many of these latter survived the first winter and made vigorous growth in 1916. They have not, perhaps, established themselves well enough to justify the prediction that the pioneer growth over considerable areas will be a willow thicket, but present indications point in that direction. In 1915 seedlings of all sorts were scarce, though many were starting at the time of our arrival. But the following season it could be seen that, while great numbers of them had been winter killed, many had survived and were growing. Since the first winter would appear to be the most critical period in the life of seedlings, and especially since the winter of 1915-1916 was unusually severe in its effects on vegetation at Kodiak, it is to be supposed that these seedlings are the beginning of the new, permanent plant covering of the country.

SEEDLINGS ESPECIALLY IN WET PLACES.

These new plants, especially the herbs, show certain peculiarities of distribution which throw much light on the factors retarding revegetation. Except the lupines, which are always in well drained situations, the new seedlings show an evident preference for wet places, or more correctly, for places which bear evidence of water action. For they are not confined to springy places, the edges of ponds and the like, but also appear in numbers on some of the outwash deposits which are not especially wet habitats.

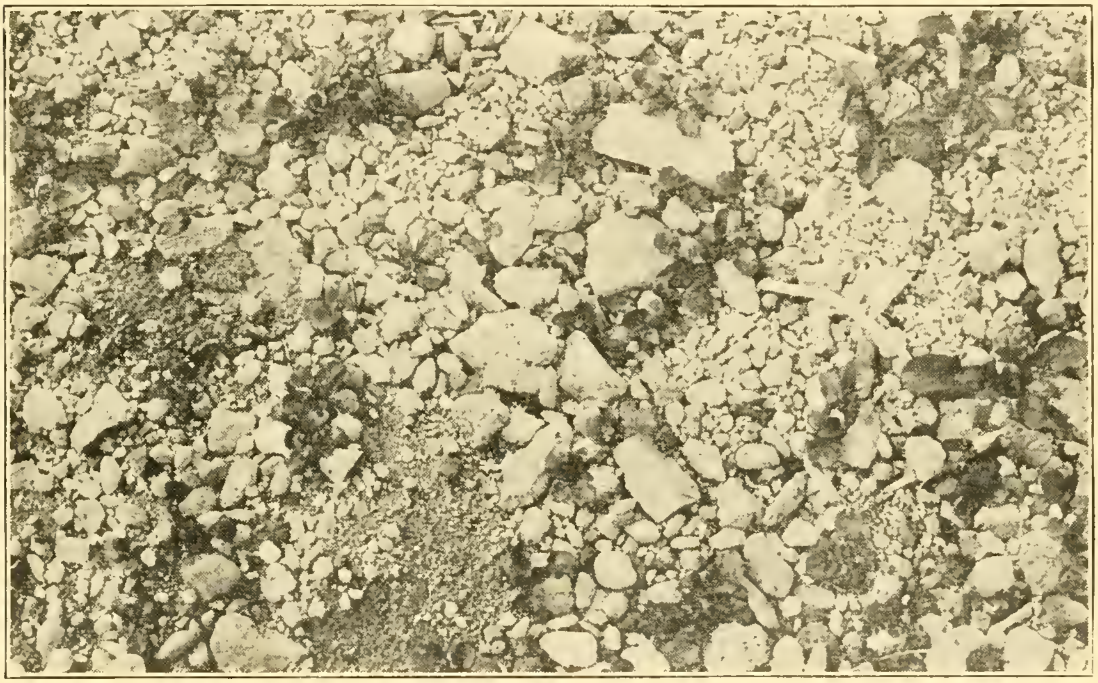
The readiest explanation of this preference would be that the ash in general has insufficient moisture to meet the water requirements of the plants. This might be expected, moreover, from the fact that the ash is purely mineral and altogether lacking in humus or similar water-holding substances, so that it dries out rapidly, giving up any water in its pores as readily as sand. Under ordinary climatic conditions this would probably be an important factor, but those who are familiar with this region will agree that it is difficult to imagine anything drying up here, so constant is the rainfall.

The season of 1915, in which occurred an unprecedented drought, gave an exceptional opportunity, however, to test the importance of this factor. Even at the close of the drought the ground was everywhere visibly moist immediately beneath the surface. To ascertain more definitely the exact situation, soil moisture determinations were made in the field. These were followed by determinations of the wilting coefficient, both by the centrifugal machine through the kindness of Dr. H. L. Shantz, and by tests of pot cultures under the writer's direction.

The results of these tests showed clearly that in all sorts of habitats there was a considerable margin of available moisture, even at the close of an unprecedented drought.

PREFERENCE FOR WET PLACES POSSIBLY DUE TO CONCENTRATION OF SALTS.

But in spite of this it could not be questioned that the rankest growth occurred in the wettest places. *Calamagrostis langsdorfii*, for example, which in normal country thrives best on well drained mountain sides, has here reached its full growth only



Photograph by Robert F. Griggs

SEEDLINGS, MOSTLY CAMPE BARBAREA, STARTING IN A WET PUMICE FLAT.

in springy places where the water is so abundant as to stand on the surface. (See page 332). For a long while it was very much of a puzzle why it did not spread onto the adjacent ground, whose soil-water content is more similar to that of the habitats it usually occupies. But finally an explanation suggested itself because of the similarity of conditions in these places to the alkali spots on the prairies. Everyone familiar with such a region as the Dakota prairies has noticed that such springy places become covered by a heavy crust of alkali salts, left behind from the evaporation of the seepage water. The places occupied by the plants in question present exactly similar conditions. Evaporation from the free water surface must similarly affect the concentration of salts. The ash contains such small amounts of the soluble salts necessary for plants that it may be supposed that only where concentrated by evaporation do they occur in amounts sufficient for vigorous growth.*

Photograph by Robert F. Griggs

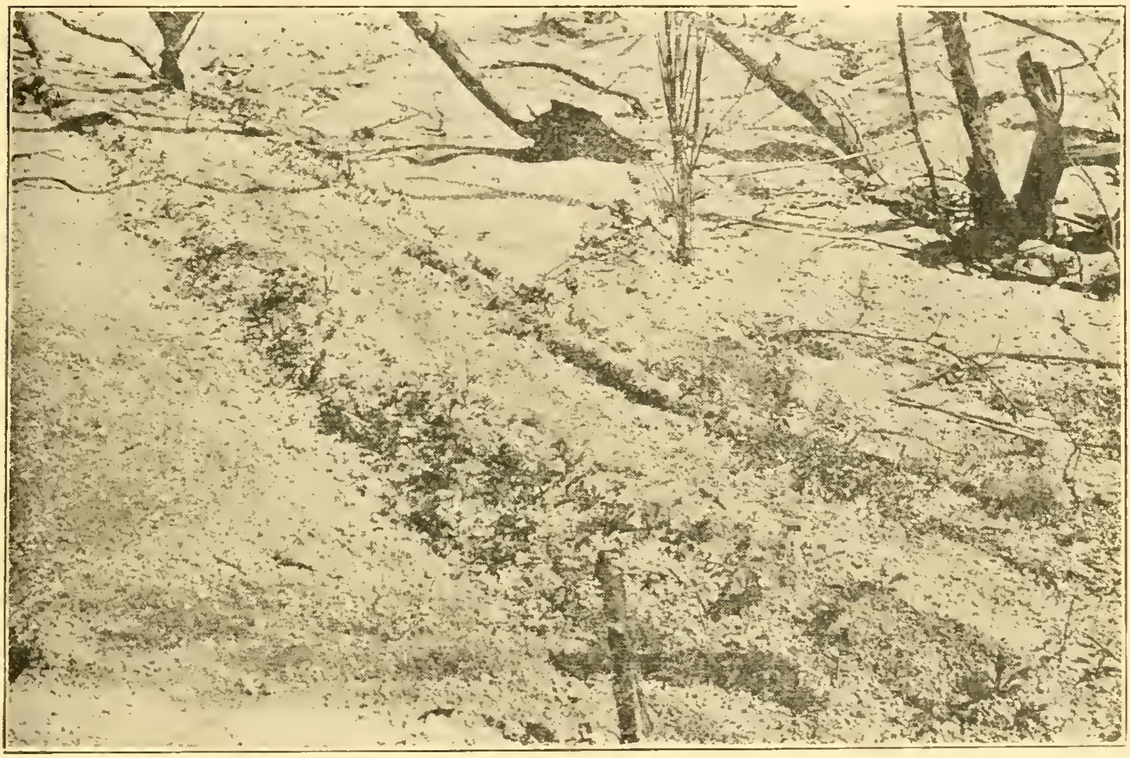
CALAMAGROSTIS LANGSDORFII APPEARING IN AN AREA WHERE WATER, COMING TO THE SURFACE, MAY HAVE ITS SALTS CONCENTRATED BY EVAPORATION.

Surrounding pumice flats, where the surface is protected from evaporation, are bare.

If this reasoning is correct, it would explain the decided advantage of the plants in the wettest places over those on the general surface of the ash where the loose top layer, acting as a

*Dr. Shipley, in the sixth paper of this series, has reported that the total soluble salt content of the ash is in general not especially low. But in analysis directed particularly toward the solution of this question, Professor C. W. Foulk, found that in the ash at Kodiak the amount of available (*i. e.*, water soluble) potash was only 0.05%, which is exactly the amount given by Hilgard as the minimum concentration requisite for plant growth. Phosphoric acid was present in an even smaller amount, which Professor Foulk described as slightly more than a trace, although it was so small that he made no attempt to give it a numerical value. The high salt content found by Shipley is probably made up, therefore, of salts not important to the growth of the plant.

mulch, prevents evaporation. It has not proved practicable as yet to submit this hypothesis to experimental test, but it has been found that it is impossible to obtain in pot cultures from small quantities of ash anything like such vigorous growth as occurs even in dry places in the field where the plants have unlimited possibilities of root extension with the consequent ability to draw upon wide areas for the necessary quantity of salts.



Photograph by Robert F. Griggs

SEEDS COMING UP WHERE COVERED UP BY THE OUTWASH OF A TEMPORARY STREAM.

General surface of the ash bare. Lower Katmai Valley.

SEEDLINGS IN DRY WATER-LAID DEPOSITS.

The distribution of only a portion of the new plants can, however, be accounted for on this hypothesis. Those coming up in outwash deposits are often so situated as to be kept better drained than the surrounding level. (See cut above.) At first I was inclined to suppose that such deposits were sufficiently contaminated by admixture of the original humus soil washed off the mountains along with the ash to present quite different and altogether more favorable conditions for the plants than the undisturbed ash deposits. But further study led me to doubt the correctness of this view, and this doubt was confirmed when it was found that pot cultures of this material were no more successful than those in which the undisturbed ash was used.

Meanwhile the field study was carried out on the hypothesis that the water content of the soil was inadequate. It was reasoned that numerous seedlings should have started in periods of wet weather, even in very unfavorable places. If this had happened many of these seedlings would have been caught in the drought and their dead and dying remains would have been easy to find. But, as a matter of fact, prolonged search failed to disclose any such, except in one solitary instance. This was considered remarkable, since, even under the conditions of the Central States, it would be easy to find numbers of seedlings which had perished in any considerable drought, even though mature plants had not suffered seriously. Moreover, since the bare ash surface is free from plant debris of any kind over considerable areas, seedlings if present could not have been overlooked. It became evident that there had never been any seedlings on the general surface.

Here, then, was another significant fact which required interpretation. The most obvious explanation would be that the ash contained some substance deleterious to the germinating seeds. In the vicinity of the crater and in certain other special localities* some such chemical is evidently present, but it is certain that no such deleterious substance is generally present. It has been shown, both by chemical analysis and by the experience at Kodiak, that there is nothing injurious to plants in the ash deposited at that distance. The pot cultures made on the return to the States showed, except in special instances, that plants do not behave differently when grown in ash from the mainland than in that from Kodiak.

It was then suspected that the reason for the barrenness of the undisturbed ash might lie in the fact that its smooth surface afforded no lodgment for seeds which, distributed largely by the terrific gales that sweep the country, are carried across the smoother surfaces and dropped in situations better adapted to catch them.

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*Dr. Shipley, in the sixth paper of this series, pages 224-229, has shown that in a few localities the ash bears so strong a concentration of ferrous sulphate as to be toxic to plants. But the occurrence of such deposits is limited to very special situations.

SEEDS PLANTED BY RUNNING WATER.

To test this hypothesis and at the same time to ascertain whether there was anything in the deposits which might prevent germination, buckwheat was sown in various habitats. At each planting the seeds were sown in two ways—by placing them in the ground and by scattering them on the surface of the ash. On our return to the Base Camp after the expedition up the valley, it was found that the seeds planted in the ground

Photograph by Robert F. Griggs

LUPINE SEEDLINGS SPREADING OUT INTO BARE ASH.

Under the protection of the old vegetation along a dune ridge, they have started in deep ash beyond the ridge. When mature they will widen the strip of protecting vegetation and facilitate further the spread of vegetation. Katmai beach, August, 1916.

had in every case come up well and showed normal growth, which continued as long as we stayed. But of those scattered on the surface of the ash not a single individual was found. Since the vicinity of the Base Camp abounds in birds, it was thought that perhaps the seeds scattered on the surface might all have been picked up by the birds, and we awaited with interest opportunity to examine similar plantings made at Katmai Village where there are no birds and the wind sweep is greater. When examined, all of these with a single exception, were found in the same condition as the others—the planted seeds had all come up, while those strewn on the surface had blown away. In one of the sowings, however, though almost all had blown away, there was one small spot where a number of seeds had come up. This was found to be in a heel mark made

Photograph by Robert F. Griggs

A BEAR TRAIL THAT SPROUTED.

The depressions in the tracks of the heavy animal caught wind-borne seeds, which drifted across the smooth surface round about without finding any place of lodgment.

by someone who had walked across the area and pressed a few seeds down into the soil with his foot! For nearly two weeks after these seeds were planted, moreover, there had been no hard blows, but considerable rain and mist, so that they may be said to have had as favorable an opportunity for catching hold as could have been given them under the climatic conditions of the region.

The same conditions are held responsible for the fringe of seedlings found along the outwash deposited by temporary streams. (See page 333). Seeds buried in the outwash

Photograph by Jasper D. Sayre

THE SAME BEAR TRAIL A YEAR LATER.

From a somewhat different position. The grasses in the track have made notable growth, but no new plants have started in the general surface of the ash, although the horsetail in the background, probably a survival, has considerably extended its runners.

deposits were protected from the wind and given favorable conditions for germination in situations where none had caught hold on the ground surface of the ash. Similar conditions, but less striking, were found at Kodiak. (See the first paper of this series, page 51).

In 1917 further striking natural demonstration of the inability of seeds to lodge in the general surface of the ash was supplied by the discovery of several bear trails that had "sprouted." The depressions made by the animal's tracks in the soft mud had served to arrest numerous wind blown seeds which otherwise would have drifted clear across the barren flats without finding any lodgment. The seeds thus caught had sprouted and grown well, proving that in that particular place, at least, the principal deterrent to revegetation was the inability of seeds to catch hold. When examined a year later, the plants growing up in the tracks had made a notable growth, as may be seen by comparing pictures taken in the two years. (See pages 336 and 337).

WIND EROSION A GREAT DETERRENT TO REVEGETATION.

But the effect of the wind on vegetation is not to be measured merely by its influence as a seed disseminator. Much more important is its effect on the soil itself. It is so violent that it keeps the surface of the ground over large areas always in an unstable shifting condition, so that plants have little opportunity to start.

The wind is, indeed, one of the most important factors retarding the revegetation of the devastated district. In another place I have shown how important it is in the vicinity of Kodiak.* Near the Volcano the total devastation and the Conformation of Katmai Valley give it a clear sweep so as to greatly intensify its effects and augment its importance.

Here the snowdrifts which accumulate during the winter are buried under a mantle of wind blown sand which is often more than half a meter thick. Our observations on such drifts in 1916 showed uniformly that the sand had all accumulated after the snow fell, for it lay as a sharply distinct layer on top of the snow and the two were not interbedded. This indicates that it was all accumulated during a short period in the spring. (See page 339). Such sand-blanketed snow is very slow in melting and in places shows little wastage even as late as the first of August, which of itself is a factor of considerable moment in retarding the renewal of vegetation on the snow covered areas.

The abrasive power of this shifting sand, as it is carried by the wind, is very considerable. There are large tracts in the upper valley in which the sandblast has cut away the bark and even abraded the wood on the northwest side of the dead trees, leaving them uninjured on the lee side. A forest of such trees is most striking testimony of what the wind can do.

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*The first paper of this series, pages 37–39.

KATMAI A VERY WINDY COUNTRY.

Unfortunately the weather records taken by the Government do not include measurements of wind velocity, so that there are no data for giving exact statements concerning the winds. The best that one can do therefore is to report some

Photograph by Robert F. Griggs

A SNOWDRIFT COVERED BY TWO FEET OF WIND-BLOWN ASH, NEAR KATMAI VILLAGE, AT SEA-LEVEL, JULY 15.

Thus protected from the sun, melting of the snow is so retarded that in many places formerly uncovered early in the season the snow now fails to melt away and is accumulating year by year.

of the effects of wind action, in order to enable the reader to form some conception of its violence. In this region the regular westerly gales approach in velocity the tornadoes which occasionally sweep our middle western states. Spurr[3] states that the natives cannot be induced to cross Katmai Pass except in fine weather, because the wind picks up stones and carries them with such force as to have killed many men. In Kodiak, a heavy dory was once picked up from the beach and carried up hill for a hundred yards, finally smashing in the front of a house before it stopped. Winds of only less violence are of common occurrence.

At our camp in the upper valley we have measured, with a weather bureau standard anemometer, winds blowing steadily 60 miles per hour, and much higher in the gusts. But the camp was in an especially sheltered situation, chosen especially with reference to avoiding such winds. Up on the mountains it was much worse, for there it picked up pieces of sharp pumice up to an inch in diameter and carried them with such force as to inflict painful blows where they struck one's flesh. Pieces even twice as large, though too heavy to be carried aloft, went scurrying over the slopes almost like dry leaves before the gale.

REVEGETATION GREATLY RETARDED BY SHIFTING STREAMS.

Another factor retarding vegetation, whose importance is almost as great as that of the wind, is introduced by shifting water currents. The streams were completely choked with ash and pumice by the eruption, and have not yet recovered from that condition. They are so overloaded with detritus that they have built up fans and flood plains many feet above the former levels of their beds. Over these great deposits of loose material they wander helplessly in many shifting channels, now here, now there, now cutting away, now building up. It is evident that no plants can obtain a foothold in such places until the streams settle down enough to give them a chance at the soil.

[3] 20th Ann. Rept. U. S. G. S., pt. 7., p. 91.

FICKLE CREEK SHIFTS ITS COURSE ONE THOUSAND FEET IN A YEAR.

Perhaps the most astonishing instance of the instability of the country was encountered when we traveled up toward Soluka Creek in 1916. Here, as elsewhere, the country looked perfectly familiar, but when we tried to find our last year's camp our memories seemed to fail us, for we could not locate it. How we could have missed it was a mystery, for it was conveniently located on the bank of a tumultuous torrent which supplied us with water. Curious to check up our unusual lapse of memory, we hunted and hunted through the dead forest in search of the old camp.

Finally we found the tent pins and the coals of the fire, just as we had left them, but the creek was nowhere in the vicinity. It had moved a thousand feet away.

Not only was the stream gone, its very bed was missing as well. The year before it had flowed in a steep sided trench, six feet below the general level, but now the ground was all smoothed off so perfectly that we could not detect the position of the former bank after the most careful search.

That some plants can start in such places, when the surface remains undisturbed, was shown by an examination of the area beyond the migrations of the stream. In 1915 this was absolutely sterile, but the next year we found in a space of about ten acres one seedling of Carex, two of *Calamagrostis langsdorfii*, two of another grass, a solitary specimen of *Chamaenerium augustifolium* and one patch of moss. Such feeble beginnings of plant life may strike the reader, familiar only with regions of luxuriant vegetation, as altogether too insignificant to deserve notice. But such is not the case, for these scattered plants, few and humble as they were, demonstrated the possibility of new plants starting in deep and pure ash deposits. Whether they were able to survive or not is questionable, but even if they succumbed they attained a size and weight far in excess of the seeds from which they originated, and their decaying bodies will furnish material for other plants to carry along the revegetation—that is, if the stream does not shift and wash them out.

HUMUS FORMATION THE REAL PROBLEM.

To the field worker the instability of the ground produced by the operation of these factors appears so important as to overshadow all else in the problem of revegetation. But experience with areas of high wind and loose soils outside the Katmai district clearly indicates that the shifting sands would be quickly caught and stabilized by the advancing vegetation if it were not for the lack of sufficient "plant food" in the ash. If such plants as start were able to grow thriftily, it would be only a relatively short time until the whole valley was again covered with luxuriant vegetation.

The real problem of revegetation is, therefore, the *nitrogen supply.* When the ash was thrown out from the Volcano in a fused condition, it was of course completely free of organic nitrogen. Dr. Shipley's work, reported in the fifth paper of this series, page 213, shows that the ash soil still remains extraordinarily poor in nitrogen compounds.

The task before us is, therefore, to follow the process by which a supply of combined nitrogen is built up in these soils as vegetation gradually returns, supplementing field observations on the plants with chemical and bacteriological examinations of the substratum. If this process of humification can be followed successfully, the knowledge so obtained will throw much light on many problems concerning the relations of plants to the soil, of great importance from both a theoretical and a practical point of view.

POTAMOGETON VASEYI IN NORTHEASTERN OHIO.

O. E. Jennings.

Potamogeton Vaseyi Robbins is an interesting little water plant which deserves to be listed among the other rare or noteworthy plants occurring in the northeastern part of Ohio. Prof. L. S. Hopkins, Kent Normal School, collected this species at Brady's Lake, Portage County, June 22, 1913, the plant then being in flower. This last year Mr. John Bright, Glenshaw, Pa., collected it with the spikes bearing partly mature achenes on July 28, 1918, at the mouth of Cowles Creek, near Geneva-on-the-Lake, Ashtabula County.

The range of the species is reported as "Quebec to Wisconsin, south to southern New York" (Britton and Brown. Ill. Flora, 1 : 83. 1913), or Maine to Ontario, south to Connecticut, New York, Ohio, Illinois, and Minnesota, local (Gray's New Manual of Botany. 1908). The species is not known to occur in northwestern Pennsylvania, although it occurs in the Scranton district, in the northeastern part of that state. (Flora of Northeastern Pennsylvania. Alfred Twining. 1917).

Two other pond-weeds were collected from Cowles Creek by Mr. Bright: Potamogeton foliosus Raf., and P. americana Cham. & Schl.

A REVISION OF THE SUBSPECIES OF PASSERCULUS ROSTRATUS (CASSIN).

Harry C. Oberholser.

Three forms of the large-billed sparrow are at present recognized. These are *Passerculus rostratus rostratus* (Cassin), from southern California and Lower California; *Passerculus rostratus guttatus* Lawrence, from Lower California; and *Passerculus rostratus sanctorum* Ridgway, also from Lower California.

These birds have been of much interest to ornithologists, partly by reason of the illusiveness of the breeding grounds of two of the forms. Moreover, they have always presented a difficult problem for the systematist, and scarcely any two authors have agreed concerning them, as the different arrangements of the forms bear witness. The present writer has for a number of years paid particular attention to these sparrows, and now the identification of a series of specimens of this species from southern California, collected by Mr. E. J. Brown for the United States National Museum, and of another small lot from Lower California, obtained by Mr. Luther J. Goldman for the Biological Survey, has made necessary a further examination of all the other material in the collection of the United States National Museum, including that of the Biological Survey. The types of all the described forms have been available, including the type of *Passerculus rostratus rostratus*, in the Academy of Natural Sciences of Philadelphia, and that of *Passerculus rostratus halophilus*, together with the type series of the latter, now in the collection of Dr. Jonathan Dwight, of New York. In addition to the birds in the above-mentioned collections, we have examined also all the sparrows of this species in the Museum of Comparative Zoölogy, at Cambridge, Massachusetts, the American Museum of Natural History, and the private collections of Mr. William Brewster, Mr. A. C. Bent, Dr. Louis B. Bishop, and Dr. L. C. Sanford. Thus we have worked over altogether 443 specimens, a series apparently adequate to settle most of the perplexing questions that have arisen regarding this group. The study of this extensive material has resulted in some interesting and rather unexpected discoveries, which seem sufficiently important to present in print. Among these results are some necessary changes in the nomenclature and systematic status of the races of this species.

It may be worth while here also to emphasize the peculiar distribution of *Passerculus rostratus* and its forms. For birds so well subspecifically differentiated, the large-billed sparrow as a species occupies during the breeding season a relatively small geographic area, extending only from the delta of the Colorado River to central western Lower California; and all its subspecies breed, so far as known, in isolated and exceedingly restricted localities. They are, however, numerous there in individuals, as is evident both from the numbers observed in summer and their abundance at various and widely separated places in winter. The most astonishing feature of their life history is the curious migration of at least two of the subspecies, knowledge of which, however, Dr. Joseph Grinnell* and others have already forecasted. In short, both *Passerculus rostratus rostratus* and *Passerculus rostratus guttatus* travel regularly far to the north or northwest of their breeding range to pass the winter; and at the same time other individuals of each form take, for the same purpose, a long southward or southwestward journey. This migration is almost, if not quite, unique, for at least no other North American passerine bird follows even similar routes. Herons and some other birds, as is well known, wander northward and in other directions after the breeding season, but not usually for the purpose of wintering; and we know of no other bird that regularly migrates both north and south from its breeding ground to pass the winter months. The data on which the above conclusions are based, together with the elaboration of the biological phases of this problem, and the discussion of the nomenclatural and other points involved, will be found in the following pages under the different subspecific headings.

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* Auk, XXII, No. 1, January, 1905, pp. 16-21; and Pacific Coast Avifauna, No. 11, October 21, 1915, p. 115.

Passerculus rostratus rostratus (Cassin).

Emberiza rostrata Cassin, Proc. Acad. Nat. Sci. Phila., VI, October (November 1), 1852, p. 184 (seashore at San Diego, California).

Chars. subsp.—Size rather large, upper surface and streaks on lower parts refuscent brown.

*Measurements.**—Male:† wing., 69.09-74.17 (average, 71.88) mm.; tail, 49.53–55.12 (53.34); exposed culmen, 12.19–13.72 (12.95); height of bill at base, 7.37–7.87 (7.62); tarsus, 22.35–23.37 (22.86); middle toe without claw, 15.75–18.03 (17.02).

Female:‡ wing, 64.01–71.88 (average, 66.80) mm.; tail, 46.48–54.36 (50.55); exposed culmen, 10.67–12.95 (12.19); height of bill at base, 6.35–7.62 (7.37); tarsus, 21.59–23.62 (22.35); middle toe without claw, 15.75–17.78 (16.26).

Type locality.—San Diego, California.

Geographic distribution.—Lower California, southern California, southwestern Arizona, and northwestern Sonora, Mexico. Breeds on Montague Island at the head of the Gulf of California, and on opposite portions of Lower California and Sonora; north along these shores to the mouth of the Hardy River in Lower California, and to the mouth of the Colorado River. Winters regularly south to Guaymas, in Sonora, and along both coasts of Lower California and its islands to Cape San Lucas, Lower California; west to the Pacific Coast of Lower California and of southern California; and north along the coast to Santa Barbara, California. Casual north to Yuma and the Colorado River in southwestern Arizona; Salton Sea, in southeastern California; San Clemente Island and Santa Cruz in central western California.

Remarks.—The type of *Emberiza rostrata* Cassin in the Academy of Natural Sciences of Philadelphia we have examined in the present connection, and it fortunately proves to belong to the race to which authors have commonly applied the name *Passerculus rostratus.* There is, however, in this subspecies, as in all forms of the species, considerable variation in the shade of the upper parts, but typical specimens are very brownish. Birds from the Colorado River, Sonora, opposite the mouth of the Hardy River, are all typical, and in worn plumage as early as the latter part of March, as specimens collected on March 25 and 26, 1894, by Dr. E. A. Mearns show; and these birds were

* Taken from Ridgway, Bull. U. S. Nat. Mus., No. 50, part I, 1901, p. 200.

† Fourteen specimens, from California, Lower California, and Sonora.

‡ Eleven specimens, from California, Lower California, and Sonora.

doubtless on their breeding grounds. Mr. Luther J. Goldman obtained typical specimens in very much worn breeding plumage on May 16, 1915, on Montague Island, Lower California. Their abraded condition and their presence here at such a late date in the spring, together with Mr. Goldman's observations on their habits given below are conclusive evidence that the birds are here on their real nesting ground. There is no record in any other locality of the presence of individuals of any form of the species later than a week beyond the middle of April (and even this is very unusual), except on their breeding grounds. Furthermore, the other races are known to breed regularly in April and even as early as March. Mr. Goldman's notes on the habits of the species as observed by him in the Colorado River delta are given below as of interest in this connection:

> Abundant on Montague Island, and with the exception of turkey vultures, the only land bird found. I found them first at the mouth of the Colorado; they range from this point south along the coast as far as my investigations took me, or to a point opposite the south end of Montague Island. The birds were found living near the river only, and frequented the long coarse salt-grass which the Cocopah Indians call "Inpah." I observed them feeding on the seeds of this grass, also working along the mud flats at low tide.

This discovery of the breeding place of *Passerculus rostratus rostratus* solves one of the most puzzling problems of North American ornithology. There are several records of the breeding of this bird in Lower California and in California, but Dr. Grinnell is probably right in considering them all mistakes of identification.* The same discovery also solves the migration mystery of this species, fully as interesting a result. With the data now at hand it is possible to work out the migration of the large-billed sparrow with some degree of certainty. Part of the individuals of the typical subspecies winter in its breeding area, but the great majority begin, by the middle of August, to leave their breeding ground, whence they move in various directions, some of them southeast along the Sonoran coast, others due south into Lower California, others west to the northern part of Lower California, and still others northwest to the coast of southern California, reaching the extremes of their winter range almost simultaneously, and regularly becoming common at Cape San Lucas and in Los Angeles County,

* Auk, XXII, No. 1, January, 1905, p. 16.

California, by at least the first of September. The earliest dates on which *Passerculus rostratus rostratus* reaches various points in its winter range are as follows: Yuma, Arizona, August 15, 1902; Ocean Beach, San Diego County, August 17, 1894; Alamitos Bay, California, August 18, 1908; Santa Cruz, California, August 27, 1895; Rosalia Bay, Lower California, August 16, 1896; San Quintin, Lower California, August 31, 1905; San Jose del Cabo, August 31, 1887; Point Lobos, Sonora, August 20, 1884.

Thus the winter range extends southward, westward, and northwestward like a very short widespread fan, with its axis at the mouth of the Colorado River. The extreme length of the winter range from northwest to southeast is approximately 1150 miles, while the known breeding area is only about 30 miles long.

The greater part of the spring migration takes place usually in late February and the first half or two-thirds of March, though some birds stay until well into April. The latest definite date of a bird known to be outside of its breeding range is that of a specimen taken at Cape San Lucas, April 22, 1859.

Of this subspecies a total of 279 specimens have been examined, from the localities in the following list:

Arizona.—Mouth of Colorado River.

California.—San Pedro, (Nov. —, 1865; Dec. 8 and 13, 1899; October 30, 1901, Jan. 17, 1885); Ocean Beach, San Diego County (Aug. 17, 1894); Sunset Beach, Orange County (Dec. 27, 1916, Oct. 22, 1915, Jan. 10, 23, and 31, 1917); Seal Beach (Dec. 19, 1914); Santa Barbara (Sept. 9, 12 and 13, 1911); Bay City (Nov. 24, 1908); San Diego (Dec. 4 and 8, 1884, Sept. 16, 1893, Nov. 16, 1861, Sept. 22, 1890, Dec. 7 and 18, 1885, March 1, 1885, Nov. 11 and 19, 1886, Sept. 5, 7, and 16, 1893, Oct. 6, 16, 17, and 23, 1893, Feb. 15, 1884, Oct. 6, 12, 14, 15 and 20, 1903, Jan. 25 and 28, 1897, Jan. 31, 1895, Aug. 21, 1893, Feb. 14, 1895, Jan. 22, 1896, Feb. 15, 1896, Dec. 11 and 18, 1894, Oct. 30, 1895); Alamitos Bay (Sept. 8 and 9, 1913, Dec. 23, 1913); Bayleys (Jan. 1, 1908); Pacific Beach, Los Angeles County (Sept. 7, 8, 10, 13, 14, 15, 22, 24, and 26, 1904, Jan. 17, 1905, Feb. 10, 1911); Alamitos, Los Angeles County (Jan. 29, 1909); Balsa Chico, Orange County (Jan. 29, 1909); Newport Landing, Los Angeles County (Feb. 23, 1886); Laguna Beach (Aug. 25, 1887, Sept. 2, 1887); Wilmington (Dec. 14, 1879).

Lower California.—San Cristobal Bay (March 16, 1884); Montague Island (May 16, 1915); Cape San Lucas (Sept. 8 and 29, 1859, Sept. 22, 1859, Oct. 24, 1859, Sept. 25 and 27, 1859, Nov. 12 and 25, 1859); Todos Santos (March 13, 1883); Todos Santos Island, La Paz (Feb. 6 and 12, 1882, Jan. 2 and 11, 1882, Dec. —, 1882, Dec. 15, 1881, Jan. 11, 1888, Feb. 7 and 14, 1887); Santo Domingo (Sept. 26 and 27, 1905); San Quintin (Aug. 31, 1905); San José del Cabo (Jan. 8 and 9, 1906, Oct. 3, 10, 13, and 18, 1887, Sept. 1, 5, 14, 17, 20, 21, 27, and 29, 1887, Aug. 31, 1887, Nov. 4 and 9, 1887); San Lucas, north of Comondu (Oct. 26, 1905); Socorro, 15 miles south of San Quintin (Sept. 1, 1905); Magdelena Island (Nov. 24, 1905); Santa Rosalia Bay, lat. 29° (Aug. 16, 1896); Playa Maria, lat. 29° (Aug. 25, 1896); Carmen Island (March 2, 6, and 7, 1887); San Rogue (March 15, 1911); Mangrove Island (Mar. 20, 1911); San Bartolome Bay (Mar. 13 and 14, 1911); Magdalena Town (Mar. 20, 1911); Abreojos Point (Mar. 16, 1911); Tiburon Island (April 12, 1911).

Sonora.—Colorado River, opposite mouth of Hardy River (Mar. 25 and 26, 1894); Mouth of Colorado River (Oct. 11, ——); Guaymas (Feb. 22, 1904, Dec. 9, 1882, Jan. 14 and 18, 1887).

Passerculus rostratus guttatus Lawrence.

Passerculus guttatus Lawrence, Ann. Lyc. Nat. Hist. N. Y., VIII, Nos. 15–17, May, 1867, p. 473 (San José del Cabo, Lower California).

Passerculus sanctorum Ridgway, Proc. U. S. Nat. Mus., V, April 3, 1883, p. 538 (ex Coues MS.) (San Benito Island, Lower California).

Chars. subsp.—Similar to *Passerculus rostratus rostratus*, but somewhat smaller, with a slenderer bill, the colors above darker, more grayish (less rufescent) and streaks on lower parts deeper, more blackish.

Measurements.—Male:* wing, 63–73.7 (average, 68.4) mm; tail, 47–53.5 (50.4); exposed culmen, 11.2–12.7 (11.5); height of bill at base, 5.6–8.1 (6.8); tarsus, 20.6–22.9 (21.8); middle toe without claw, 15–18 (16.3).

Female:† wing, 62–68.3 (average, 65.8) mm.; tail, 46.5–53 (49.5); exposed culmen, 11.7–13 (12.3); height of bill at base, 6–7.4 (6.6); tarsus, 19.2–22.5 (21); middle toe without claw, 15–16.5 (16).

Type locality.—San José del Cabo, Lower California.

Geographic distribution.—Coastal region of Lower California and southwestern California. Breeds on the San Benito

* Ten specimens, from Lower California.

† Ten specimens, from Lower California.

Islands, central western Lower California. Winters on the coast and islands of western Lower California, south to Cape San Lucas, and to La Paz in southeastern Lower California; and north along the Pacific Coast to Los Angeles County, California.

Remarks.—The present form is now seen to be somewhat smaller than *Passerculus rostratus rostratus*, but there is much individual variation in this as in other respects, so much, in fact, that all the differences between these two forms are fully covered; and consequently *Passerculus rostratus guttatus* is certainly but a subspecies of *Passerculus rostratus rostratus*, though a very distinct one.

The bird described by Mr. Ridgway as *Passerculus sanctorum**, from San Benito Island, off the western coast of Lower California, has commonly been considered a different subspecies, and Mr. William Brewster has indorsed this view in his careful study of the specimens obtained by Mr. M. Abbott Frazar in the Cape region of Lower California.† A re-examination, however, of the types of *Passerculus rostratus guttatus* and *Passerculus rostratus sanctorum*, together with a large amount of new material, particularly from the San Benito Islands, shows that they certainly belong to one and the same form. The type of *Passerculus rostratus guttatus* is a winter bird of rather unusually dark coloration and is possibly a bird of the year. One of the two original specimens of *Passerculus rostratus sanctorum* Ridgway has the bill practically as slender as the type of *Passerculus rostratus guttatus;* in fact, there is much more difference in this respect between the type and paratype (No. 70637, U. S. Nat. Mus.) of *Passerculus rostratus sanctorum* than between the type of *Passerculus rostratus sanctorum* and the type of *Passerculus rostratus guttatus*. Furthermore, *Passerculus rostratus sanctorum* is darker, much more grayish (less brownish) in fresh autumn and winter plumage than in the spring and summer. Accordingly, a series of freshly molted specimens from San Benito Island, collected on September 7, 8, and 9, 1896, so closely resemble the type of *Passerculus rostratus guttatus* that they must be the same. One of these individuals (No. 153975, U. S. Nat. Mus.), taken on September 9, 1896, is as good a match for the type of *Passer-*

* Proc. U. S. Nat. Mus., V, April 3, 1883, p. 538.

† *Cf.* Bull. Mus. Comp. Zoöl., XLI, No. 1, September, 1902, pp. 139-141.

culus rostratus guttatus as one could ask for; in fact, they are difficult to distinguish at all, except that the type is somewhat duller, possibly from age. Several others of this same series are exceedingly close. One example, No. 90064, U. S. Nat. Mus., taken at San José del Cabo, Lower California, January 20, 1883, is intermediate between the present race and *Passerculus rostratus halophilus*,* (which, indeed, is a perfectly good subspecies, but it is nearer the present form.

From these facts it is evident that *Passerculus rostratus sanctorum* Ridgway becomes a synonym of *Passerculus rostratus guttatus*, which disposition, it is interesting to note, is the same as that originally made by Mr. Ridgway himself, who really intended to discredit *Passerculus sanctorum* Coues MS., but inadvertently gave it nomenclatural status.† The reverse side of the labels of the two original specimens of *Passerculus sanctorum* bear in Mr. Ridgway's handwriting "*P. guttatus* Lawr.! (R. R.)." A further light on the history of these specimens is furnished by the subsequent notation by Dr. Coues on the back of the label of the specimen which was not chosen as the type, underneath what Mr. Ridgway had written, which reads as follows: "Scarcely! stet *sanctorum*—C."

The juvenal plumage and that of the first autumn are, in so far as the upper parts and pectoral streaks are concerned, much more brownish than adults, and much more closely resemble *Passerculus rostratus rostratus*. Indeed, occasional specimens are difficult to distinguish.

Mr. H. B. Kaeding has recorded‡ *Passerculus rostratus rostratus* as occurring on the San Benito Islands on July 14, 1897, and at San Juanico Bay, June 12, 1897. The former record certainly refers to *Passerculus rostratus guttatus*, being from the breeding region of this form, but the bird from San Juanico Bay, which is some distance south of Abreojos Point on the western coast of Lower California, is most probably the same as *Passerculus rostratus halophilus*. A series of 17 specimens taken by Mr. E. J. Brown at Sunset Beach, Orange County, California, from November 13, 1916, to January 31, 1917, and at Anaheim Landing, Orange County, California, October 5, 1916, some of which are perfectly typical, others

* For the characters distinguishing this subspecies, *cf. postea*, p. 353.
† Proc. U. S. Nat. Mus., V, April 3, 1883, pp. 538-539.
‡ Condor, VII, September, 1905, p. 135.

verging toward *Passerculus rostratus rostratus*, constitute the first record of this subspecies for California; and Mr. Brown has already announced this discovery.*

The present subspecies breeds commonly on the San Benito Islands, where Mr. H. B. Kaeding found fresh eggs as early as March 27-30, 1897.†

The migration of *Passerculus rostratus guttatus* proves to be nearly as astonishing as that of *Passerculus rostratus rostratus*. In this case, however, the line of travel is, so far as known, only northwest and southeast along the coast for about the same distance in each direction from the breeding area, the linear extent of the winter range being about 900 miles. This subspecies is apparently confined to the immediate coast, and in Lower California also to the Pacific Coast, except in the Cape San Lucas region, where it occurs along the Gulf of California as well; but there is no interior record for either Lower California or California.

We have examined 125 examples of this species, from the localities given below.

California.—Sunset Beach, Orange County (Dec. 13, 20, and 27, 1916, Jan. 10 and 31, 1917, Nov. 13 and 20, 1916); Anaheim Landing, Orange County (Oct. 5, 1916); Alamitos Bay (Sept. 9, 1913); San Pedro, Los Angeles County (Oct. 30, 1901).

Lower California.—San José del Cabo (Dec. —, 1859 [type], Jan. 20, 1883, Jan. 8, 1906, Oct. 3 and 10, 1887, Nov. 9, 1887, Sept. 23, 1887); San Benito Island (July 12, 13, and 14, 1897, Sept. 7, 8, and 9, 1896, April 25 and 26, 1906, Mar. 1, 21, and 28, 1897, Mar. 9, 28, 29, 30, and 31, 1911); San José Island (Feb. 12, 1909); West Benito Island (Mar. 9, 1911); Carmen Island (Mar. 6, 1887); Abreojos Point (Mar. 16, 1911).

* Auk, XXXIV, No. 3, July, 1917, p. 340.

† Condor, VII, September, 1905, p. 136.

Passerculus rostratus halophilus (McGregor).

Ammodramus halophilus McGregor, Auk, XV, No. 3, July, 1898, p. 265 (Abreojos Point, Lower California).

Chars. subsp.—Similar to *Passerculus rostratus guttatus*, but upper surface duller, darker, and more greenish (less purely grayish), the dark streaks on pileum and interscapulum less sharply defined; sides of the head, including particularly the supraloral region, more suffused with yellowish; streaks on lower parts heavier, more blackish, and without brownish edgings.

*Measurements.**—Male:† wing, 66.80–70.61 (average, 69.09) mm.; tail, 42.93–52.32 (50.29); exposed culmen, 12.70–12.95 (12.62); height of bill at base, 6.35–7.62 (6.60); tarsus, 20.32–22.61 (21.59); middle toe without claw, 15.49–17.02 (16.00).

Female:‡ wing, 63.50–69.60 (average, 64.77) mm.; tail, 45.21–51.05 (47.50); exposed culmen, 12.19–13.21 (12.70); height of bill at base, 6.10–6.86 (6.35); tarsus, 20.32–22.35 (21.34); middle toe without claw, 14.48–16.76 (15.75).

Type locality:—Abreojos Point, central western Lower California.

Geographic distribution:—The southern half of the western coast of Lower California. Breeds at Abreojos Point, central western Lower California and probably also at San Juanico Bay somewhat farther south. Winters south to Cape San Lucas.

Remarks.—This race differs from *Passerculus rostratus rostratus* so very strongly in its darker, more greenish upper surface and in its slenderer bill that no special comparison is necessary. A careful examination of the type series and also of winter birds from the Cape San Lucas region, and their comparison with both *Passerculus rostratus rostratus* and *Passerculus rostratus guttatus* show that *Passerculus rostratus halophilus* is an excellent subspecies. The three races of this species may be readily distinguished by the color of the upper surface alone, since *Passerculus rostratus rostratus* is a brownish bird, *Passerculus rostratus guttatus* a grayish form, and *Passerculus rostratus halophilus* decidedly greenish. Mr. William Brewster's objections§ to the recognition of *Passerculus rostratus halophilus* have been fully met by the acquisition of a good series of breeding examples of *Passerculus rostratus guttatus*,

* Taken from Ridgway, Bull. U. S. Nat. Mus., No. 50, part I, 1901, p. 202.
† Nine specimens, from Lower California.
‡ Twelve specimens, from Lower California.
§ Bull. Mus. Comp. Zoöl., XLI, No. 1, September, 1902, pp. 139-140.

so that it is possible to compare both these forms in nuptial plumage; furthermore, the identification of *Passerculus sanctorum* Coues with *Passerculus rostratus guttatus* Lawrence furnishes additional evidence of the distinctness of *Passerculus rostratus halophilus*, since it satisfactorily disposes of the mystery surrounding the breeding place of *Passerculus rostratus guttatus*. The present form, however, is clearly but a subspecies of *Passerculus rostratus rostratus*, since some individuals show vergence toward *Passerculus rostratus guttatus*, and we have already made mention* of the inclination that some specimens of *Passerculus rostratus guttatus* have toward *Passerculus rostratus halophilus*. In breeding plumage the present subspecies becomes very dark on the back, since the abrasion of the plumage more or less obliterates the lighter areas and accentuates the dark markings.

So far as known, *Passerculus rostratus halophilus* is a very local race, breeding certainly only at Abreojos Point on the western coast of Lower California, where Mr. H. B. Kaeding found eggs on April 19, 1897.† He also mentions, under the name *Passerculus rostratus*, sparrows of this species common at San Juanico Bay, on June 12, 1897, which, on geographic grounds, should belong to *Passerculus rostratus halophilus*, but he appears to have collected no specimens there. The only certain wintering ground of *Passerculus rostratus halophilus* is the southern portion of Lower California, but it very possibly migrates also northward from its breeding ground, as do the two other subspecies of *Passerculus rostratus*.

Thirty-nine specimens of this form have been examined, from the localities given below:

Lower California.—Abreojos Point (April 19, 1897 [type], June 17, 1897, March 16, 1911); San Jose del Cabo (Jan. 8 and 9, 1906); Santa Maria Island (March 19, 1911); southern end of Magdalena Bay (March 20, 1911); Mangrove Island (March 20, 1911); Magdalena (March 21, 1911).

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* *Cf. antea*, p. 353.

† Condor, VII, September, 1905, p. 136.

NEW SPIDERS FROM OHIO.*

W. M. Barrows.

The following nine species of spiders do not appear to have been described. The type specimens will be retained in the collections of the Department of Zoology, Ohio State University, Columbus, Ohio.

Drassodes auriculoides n. sp.

Female: Length 10 mm. Cephalothorax brownish yellow, front of head and mandibles much darker and redder, a dark line around the edge of the cephalothorax. Hairs on the mandibles with a dark spot at the base of each. Legs yellow, these and the cephalothorax covered with a thin down of white hairs among which are some black hairs. Feet with heavy dark scropulæ which thin out toward the middle of the metatarsi. Sternum yellow, with a border of heavy brown chitin, truncated in front, widest at second coxæ, with a right angle point between the posterior coxæ. Posterior eyes in a straight row, rather far from the front row. P. M. E. rectangular, almost square, close together. (Pl. XV, Fig. 4a). Abdomen long and low, widest at the posterior third, narrowing abruptly to an obtuse point. Color of the abdomen under alcohol a light brownish gray, due to the mixture of black and white hairs, a long narrow light-colored basal stripe, becoming dark gray in the middle, ends in a series of irregularly placed dark round spots a short distance in front of the tip. Spinnerets, long, yellowish brown, approximately equal. Venter lighter than dorsum, much lighter in front of epigastric furrow. Epigynum brown, consisting of three lobes, the middle nearly square, the side ones each resembling a human ear. (Plate XV, Fig. 4b).

One female under a board in a high dry pasture, Rockbridge, Ohio, September 30, 1917.

Prosthesima lacca n. sp.

Male: Length 2 mm. Cephalothorax almost black, bare and shiny, as if made of a dark wood showing some brown grains, freshly lacquered. Oval shield on base of abdomen with the same characters, except that it is hairy. Anterior coxæ dark, the others pale yellow. All the tarsi and metatarsi pale yellow, the femur, patella and tibia of the first legs dark, shining, the others dark before and behind, but light above. Sternum and endites dark, shiny. Abdomen, above black with bluish reflections, rather shiny, below lighter. Tarsus

*Contribution from the Department of Zoōlogy and Entomology, Ohio State University, No. 55.

of palp almost spherical, on the outside a dark forked process the upper tooth of which turns outward; above this is the end of the short, fine tube which ends on a clear swollen area; on the inside of the palpal organ is another forked process directly opposite the first but not quite so large nor so clearly marked. (Pl. XV, Fig. 3).

One male from Columbus, Ohio, June 10, 1917.

Prosthesima lutea n. sp.

Male: Length 5.5 mm. Head, thorax, legs and shield on the base of the abdomen uniform light brownish yellow. Abdomen cream colored, covered with long black hairs, which gives the whole a greenish tinge, the dark edges of a long narrow lanceolate basal mark are visible through the shield and extend a short distance beyond the second pair of muscular impressions. The first pair of muscular impressions are rather prominent, just inside the edge of the shield. Spinnerets and venter cream colored. Tibiæ of first and second legs with one spine on the anterior side below, slightly beyond the middle, and one at the extreme end, none on the posterior side. P. M. E. large, oval, close together. P. S. E. about the same size as the A. S. E. and close to them. A. M. E. large, half their diameter apart, almost touching the A. S. E. Palpal organ ending in a tube which curves upward toward the tip of the tarsus. Tibia of palp with a short spur on the outside, which is prolonged dorsally in a delicate spine. (Pl. XV, Figs. 5a, 5b).

One male from Sugar Grove, Ohio, July, 1915.

Cybaeus silicis n. sp.

Male: 8 to 10 mm. long. Cephalothorax and legs light brownish yellow. Cephalothorax high, evenly rounded, a dark V-shaped mark with its point at the dorsal groove, a narrow dark line at the extreme margin. Dorsal groove dark. Mandibles reddish, robust at base, furrow armed in front with two large and one small teeth, and in back with three small and three or four minute teeth. Abdomen high, highest at the front, widest behind the middle, dull gray with a white basal lanceolate line and six or seven white spots on each side of the median line, the anterior spots round, the middle elongate, the posterior diagonal lines or joined with those of the opposite side to form bars. Venter white. Palpus long, femur longer than patella plus tibia, patella widened distally with a group of about ten minute conical spines on the extended side; tibia with a large, flattened tooth. (Pl. XV, Fig. 7b).

Female much like the male. Epigynum with a broad opening which apparently opens below into a pair of dark sacs, at the sides are two round dark bodies. (Pl. XV, Fig. 7a).

Several pairs from Bainbridge, Ohio, August 17, 1917, where they were found on the sides of large boulders more or less buried in leaves and humus in a deep ravine. A few specimens from Rockbridge, Ohio.

Grammonota vittata n. sp.

Male: 2 mm. long. Female: 2.7 mm. long. Head, cephalothorax, and legs light brownish yellow. Eyes surrounded by dark rings. Edges of cephalothorax slightly darker, dorsal groove dark. Sternum yellow, darker at the edge. Abdomen grayish yellow, a dark sooty, median stripe extends from the front edge two-thirds of the length of the abdomen, becoming narrower posteriorly. Posterior third of abdomen showing traces of the stripe and marked by five or six narrow, curving, transverse, light lines, which divide this part into five or six poorly defined chevrons. Six well defined teeth on the anterior edge of the furrow of the cheliceræ. Beneath the tibia of the first leg of the female are three pairs of long slender spreading spines, beneath the metatarsus are two pairs of similar spines. There is one slender spine above at the end of the patella and one at the basal third of the tibia. The spines in the male are weakly developed, except the two pairs under the anterior metatarsi. The male palpus is much like that of G. inornata, except that the tarsus in vittata flares on the outside into a long flange and the tooth on the tibia is broad and thin. (Pl. XV, Figs. 1a, 1b, 1c. 1d).

This species is about the same size as inornata, but is easily distinguished by the stripe, the light color, and the well developed spines.

Several males and females from Hebron, Ohio, near the canal, October 3, 1918. In one case a male and female were found together in a small curled dead leaf about a foot above the ground.

Oxyptila marshalli n. sp.

Male: Length 3 mm. A very striking spider, the cephalothorax a rich dark golden brown, marked with black as follows: A central narrow dark line ending at the posterior slope, a dark line on each side of this runs parallel with it from the eye region, bending toward it just before it ends, the three lines end parallel to each other and very close together, the side lines lie in an area of dark pigment which forms two indistinct stripes. Two broad dark stripes lie on the outer sides of the cephalothorax bordered on the outside by a very narrow light stripe which is in turn bordered by a hair line of black. Abdomen much wrinkled, each ridge dark, each depression light. Sternum and coxæ light yellow, a short dark streak at the posterior point of the sternum. Abdomen colored below as above, except that there is some pink color present. Like *O. nevadensis*, metatarsi I and II have two pairs of spines below and two on each side just above and in front of these. (Pl. XV, Fig. 2b). The A. M. E. are only half as large as the P. S. E. and only slightly larger than the P. M. E. Femur I has one small spine above and three in a row in front of this. Tibia of the palp with three projections. (Pl. XV, Fig. 2a).

One male under a dry log in pine woods at Sugar Grove, Ohio, September 11, 1917.

This species is named for Walter W. Marshall, of Sugar Grove, Ohio, a promising young zoölogist and former student of the Department of Zoölogy of Ohio State University, who died in his country's service at Camp Sherman, Chillicothe, Ohio, on October 4th, 1918. Mr. Marshall was interested in the *Phalangida* and was collecting with me when the specimen described above was taken.

Phidippus hirsutus n. sp.

Male: Length 9 mm. Head high and swollen, highest at the level of the second row of eyes. Color in alcohol: Cephalothorax (somewhat rubbed) dark red, grading to black around the eyes, from the depression between the posterior eyes a narrow black line runs posteriorly to the border, on each side of this are two or three black lines which run diagonally backward and curve outward toward the edge, hairs around the eyes long, the upper ones black and the lower white. Clypeus with long white hairs which extend half way down the mandibles. Sides of cephalothorax with a sparse covering of white hairs. Lower part of mandibles green, irridescent. Femora dark reddish brown, extremities lighter, the front side of the first two femora covered with bright yellow scales and some long yellow hairs; lower side of patella and tibia with a fringe of long yellow hairs. Palpus with white scales above and long white hairs on the outside. Abdomen rubbed above, but shows no indications of lines or spots. The spur on the tibia of the palp is divided into three teeth, the tube of the palpal organ is broad, thin and blade-like. (Pl. XV, Fig. 6b).

One male, Rockbridge, Ohio, (Cantwell Cliffs), October 4, 1914.

Female: A female which appears to belong to the same species was taken at the same place in July, 1914. It is stouter and heavier than the male, but very much like it. The eye region is black with some bronze irridescence, sparsely clothed with black hairs. Cephalothorax dark red, sparsely covered with white scales, white hairs and black hairs. Dark lines like those in the male are present. Clypeus snow white, with some long white hairs. Palps with a brush of long white hairs. Legs well covered below with long white hairs, white scales and some black hairs. Abdomen dull tan color, due to a mixture of short tan and white hairs, through which extend long black and some long white hairs. Venter similar in color to dorsum. Young specimens alive appear to be a mass of long gray hairs. On these a light line is visible at the base of the abdomen and there are indications of some light diagonal lines. The epigynum is longer than wide. (Pl. XV, Fig. 6a).

Sittacus cursor n. sp.

Male: Length 2.3 mm. Color alive, entire upper surface a uniform silver gray. Color under alcohol, the cephalic plate bluish black, thorax yellow brown, a wide black line encircling the thorax from the base of one palp to the base of the other. Cephalothorax and abdomen uniformly covered with white hairs. Clypeus light. Three prominent bristles between the A. M. E., the upper one bent dorsally. Abdomen marked with small dark spots, which at the posterior form four chevrons, sides marked by many longitudinal dark lines, base above with long white and some long black hairs. Anterior femora black above. Anterior patellæ spotted in the middle, with a narrow dark band at each end. Femora below with a narrow band at base, a wide one in the middle and another at the end. Sternum mottled with dark pigment. Tibia of palp very large with a long spine. (Pl. XV, Fig. 8a). The male runs with great rapidity.

Female: Length 2.7–4.0 mm. Color alive, uniform brownish gray, evidently due to the many dark orange hairs mixed with the white. Color under alcohol, like the male, except that the spots on the abdomen are larger and more irregular. Epigynum a triangular area, a single opening at the anterior end, and two circles near together at the posterior. In one specimen the circles are side by side, in the other specimen they are one in front and the other behind. (Pl. XV, Fig. 8b).

One male from Columbus, Ohio, July 2, 1917; one female, from Buckeye Lake, Ohio, June 24, 1917; one female from Columbus, Ohio, June 24, 1918, in a nest on a stone at the edge of a timothy field.

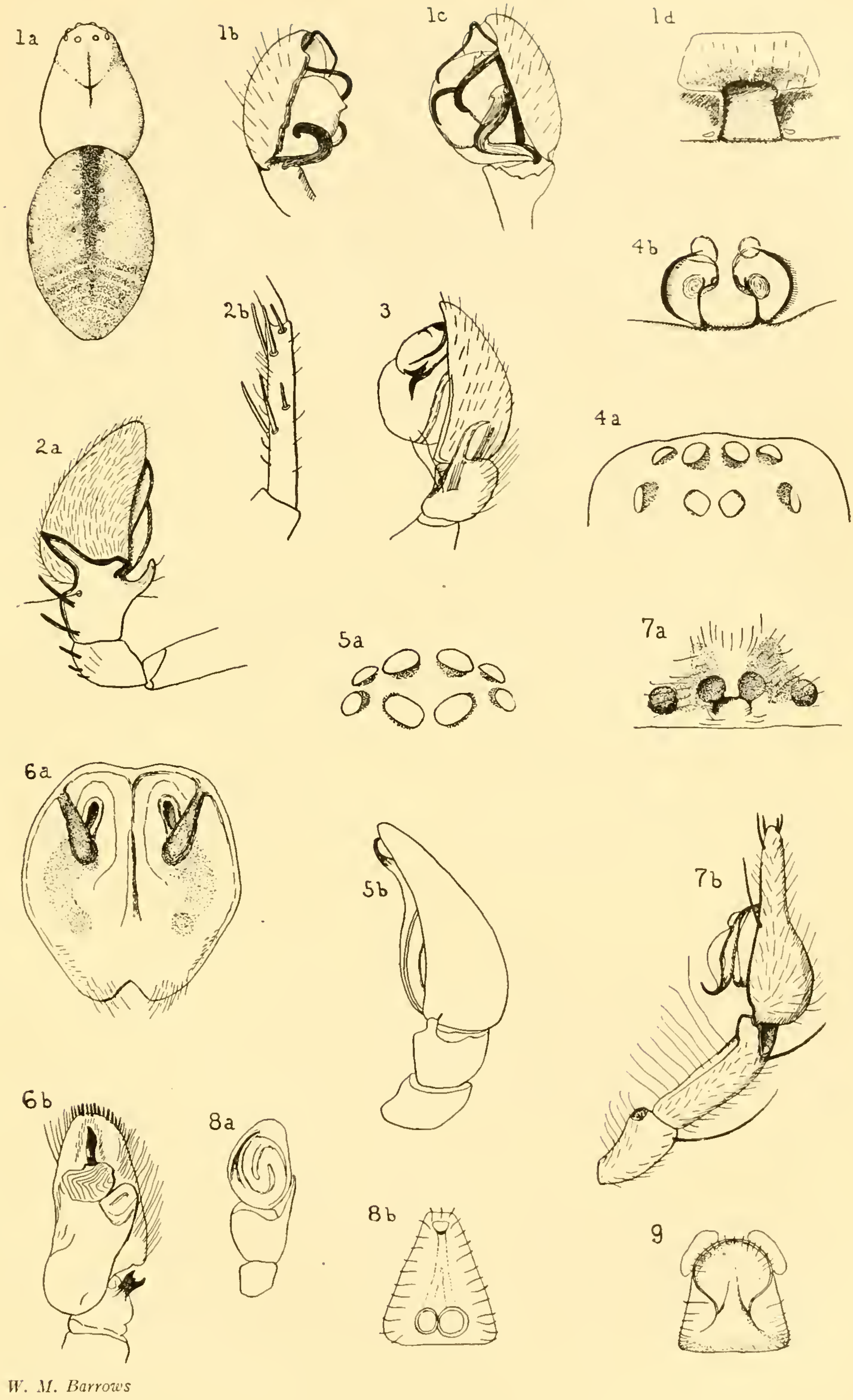
Sassacus smaragdinus n. sp.

Female: Length 4.5 mm. Color alive a brilliant emerald green, the basal band on the abdomen, sides of cephalothorax and scales on palpi and legs brilliant yellow. Color in alcohol, integument dull black, covered with scales the color of which changes with the angle of the light from deep purple to green. This species is rather closely related to S. papenhoei, but differs in the following particulars: The cephalothorax is practically flat on top (slightly higher at the third eyes) and slopes abruptly to the posterior border, the A. S. E. are only one-third as large as the A. M. E., the mandibles are inclined forward so that they protrude in front of the eyes when viewed from above, the lip is longer than wide, the clypeus is red, showing no white, except a few very long white scales which project between the bases of the mandibles. Femora black. Patellæ and tibiæ dark red brown. Metatarsi yellow, with a dark band at end. Tarsi yellow. Claws and hairs of foot black. Patella and tibia I with a patch of brilliant yellow scales above at distal end. Similar patches of yellow scales occur on patella, tibia and tarsus of the palp. The cephalothorax is widest at the middle of the thorax where it slopes abruptly downward, is narrowed gradually forward and suddenly backward from this point. (Epigynum, Pl. XV, Fig. 9).

One female from the high upland prairie above Cantwell Cliffs, five miles south of Rockbridge, Ohio, July 8, 1918. This specimen was in a silk cocoon in a curled Smilax leaf and was apparently ready to lay eggs.

EXPLANATION OF PLATE XV.

1. *Grammonota vittata.* 1a, dorsal view of male; 1b, outside of right palpal organ; 1c, inside of right palpal organ; 1d, epigynum.
2. *Oxyptila marshalli.* 2a, outside of right palpal organ; 2b, anterior side of right metatarsus.
3. *Prosthesima lacca,* outside of left palpus.
4. *Drassodes auriculoides.* 4a, eyes from above; 4b, epigynum.
5. *Prosthesima lutea.* 5a, eyes from above; 5b, palpus.
6. *Phidippus hirsutus,* 6a, epigynum; 6b, palpal organ.
7. *Cybaeus silicis.* 7a, epigynum; 7b, left palpus.
8. *Sittacus cursor.* 8a, palpus; 8b, epigynum.
9. *Sassacus smaragdinus,* epigynum.



W. M. Barrows

MOSSES OF SEVERAL OHIO COUNTIES.

Edo Claassen.

In the course of the last 20 years excursions were undertaken now and then, mostly in Northern Ohio, to prepare a list of the Moss Flora of that part of the State. The names of the counties where the species were collected are abbreviated: C stands for Cuyahoga, E for Erie, G for Geauga, L for Lake, Li for Licking, M for Medina, O for Ottawa, P for Portage, Pe for Perry and S for Summit.

More than 1000 boxes and packages, containing an almost innumerable number of specimens, represent the result. They are incorporated in the collector's herbarium. Their description is found in Lesquereux and James' Manual and a key, helping in the determination, was published by Barnes and Heald in 1896. Several of these mosses were never found fruiting, as for instance, *Eurynchium Boscii* and *Myurella Careyana*, others such as *Climacium americanum*, *Bryum roseum* and the *Sphagnum* once only. Quite a number of sterile ones, however, are yet on hand, waiting to be identified, which may be possible only by comparing them with the *Exisccatæ.*

It is the ardent wish of the writer that this list may induce students of Botany to make themselves acquainted with the highly interesting mosses. They can be assured that without fail great pleasure will be their reward.

List of Mosses.

I. **Sphagnaceæ** (Peat Mosses).

Sphagnum acutifolium, Ehrh. On the ground; C, S.
Sphagnum cuspidatum, Ehrh. On the ground; C, L. S.
Sphagnum cymbifolium, Ehrh. On the ground; C. G. P. S.
Sphagnum recurvum, Beaur. On the ground; S.
Sphagnum subsecundum, Nees. On the ground; C, L.

II. **Bryaceæ** (True Mosses).

a. Acrocarpi.

Atrichum angustatum, Br. and Sch. On the ground and rock; C, E.
Atrichum undulatum, Beaur. On the ground; C.
Aulacomnium heterostichum, Br. and Sch. On the ground; C, L, P, S.
Aulacomnium palustre, Schwaeger. On the ground; C, G, L, P, S.

Aulacomnium palustre polycephalum, Schwaegr. On the ground; C, P.
Barbula nucronifolia, Br. and Sch. On the ground (base of tree); C.
Barbula ruralis, Hdw. On the ground (sand); E.
Barbula unguiculata, Hdw. On the ground; C.
Bartramia pomiformis Hdw. On the ground; C, L.
Bryum argenteum, L. On the ground; C, E.
Bryum bimun, Schreb. On the ground, rock and rotten wood; C, P.
Bryum caespititium, L. On the ground, rock and rotten wood; C, L, S.
Bryum inclinatum, (Lw.) Br. and Sch. On decomposed slate; S.
Bryum intermedium, Brid. On the ground, rock and rotten wood; C, E, L, Li, O.
Bryum roseum, Schreb. On rotten wood and leaves; C, L, O, S.
Ceratodon purpureus, L. On the ground, rock and rotten wood; C, E, L, S.
Desmatodon arenaceus, Sull., Lesq. On rock; C, L, Li, S.
Dicranella heteromalla, Schimp. On the ground, rock and rotten wood; C, L, Li, S.
Dicranella rufescens, Schimp. On the ground; C.
Dicranella varia, Schimp. On the ground and slate; C.
Dicranum flagellare, Hedw. On rotten wood; C, L.
Dicranum fulvum, Hook. On rock; C, S.
Dicranum fuscescens, Turn. On rotten wood; C.
Dicranum scoparium (L), Hedw. On the ground; C, L.
Didymodon rubellus, Br. and Sch. On the ground over rock; C.
Diphyscium foliosum, Mohr. On the ground; C.
Discelium nudum, (Dicks.), Brid. On the ground; C.
Ditrichum pallidum, (Schreb.), Hampe. On the ground; C.
Ditrichum tortile, (Schrad.), Lindl. On the ground; C.
Drummondia clavellata, Hook. On bark; C.
Ephemerum serratum, Hampe. On the ground; C.
Fissidens adianthoides, Hdw. On the ground; C, O.
Fissidens cristatus, Wils. On rock; C.
Fissidens incurous, Schwaegr. On rock; C.
Fissidens obtusifolius, Wils. On rock; C.
Fissidens sublasilaris, Hedw. On rotten wood; C.
Fissidens touxifolius, Hedw. On the ground, rock and rotten wood; C, L, O.
Fontinalis antipyretica, L. On rock in water; C, E, L.
Funaria hygrometrica, L. On the ground, rock and rotten wood; C, E, G, L, P, S.
Grimmia apocarpa, Hedw. On rock; C, O.
Gymnostomum calcareum, Nees and Hornsch. On rock; C, O, S.
Gymnostomum curvirostrum, Hewd. On rock; C.
Gymnostomum rupestre, Schwaegr. On rock; C, L, S.
Hedwigia ciliata, Ehrh. On rock; C, G, L, S.
Leptobryum pyriforme, (L.) Schimp. On ground and rock; C, L, O, S.
Leucobryum glaucum, (L.) Schimp. On the ground; C, G, S.
Mnium affine, Bland. On the ground and rock; C, L.
Mnium cuspidatum, Hdw. On the ground; C, P.

Mnium Drummondii, Br. and Sch. On the ground; C.
Mnium punctatum, Hdw. On the ground and rotten wood; C.
Mnium rostratum, Schwaegr. On the ground and rock; C.
Mnium serratum, Laich. On the ground and rock; C, L.
Orthotrichum anomalum, Hedw. On rock; O.
Orthotrichum strangulatum, Beaur. On bark; C, G, Li, M.
Philonotis fontana, Brid. On the ground; C, G, L.
Physcomitrium immersum, Sull. On the ground; C, G.
Physcomitrium turbinatum, C. Muell. On the ground; C.
Pleuridium alternifolium, Brid. On the ground; C.
Pogonatum brevicaule, Beaur. On the ground; C, L.
Polytrichum commune, L. On the ground; C, G, L, P.
Polytrichum juniperinum, Willd. On the ground; C, P.
Polytrichum Ohioense, Ren. and Card. On the ground; C, G, L, P, S.
Schistostega asmundacea, Web. and Mohr. On the ground in cave; P.
Tetraphis pellucida, Hedw. On rock and rotten wood; C, P, S.
Timmia megapolitana, Hedw. On the ground; C, S.
Ulota crispa, (L.) Brid. On bark; C.
Ulota crispula, (Bruch) Brid. On bark; C.
Ulota Hutchinsiæ, Schimp. On rock (erratic boulder); C.
Webera albicans, Schimp. On the ground; C.
Webera elongata, Schwaegr. On rock; L.
Webera nutans, Hedw. On the ground, peat and rotten wood; C, Li, P, S.
Weisia viridula, Brid. On the ground; C.

C. Pleurocarpi.

Amblystegium adnatum, (Hedw.) Austin. On old bark and rock; C, L.
Amblystegium compactum, (C. Muell.) Austin. On dripping rock; C.
Amblystegium confervoides, (Brid.) Br. and Sch. On rock; C.
Amblystegium irriguum, (Wils.) Br. and Sch. On moist ground, rock and rotten wood; C, G, L, S.
Amblystegium irriguum spinifolium, Schimp. On moist ground and rock; C, P.
Amblystegium riparium, (Hedw.) Br. and Sch. On moist ground and old wood; M, S.
Amblystegium riparium fluitans. Floating in water; C.
Amblystegium serpens, (Hedw.) Br. and Sch. On old bark, wood and rock; C, L, P, S.
Amblystegium varium, (Hedw.) Lindl. On the ground, rock and rotten wood; C, L, Li.
Anacamptodon splachnoides, Brid. Around moist knot hole of sugar maple; C.
Anomodon attenuatus, Huebn. On the ground, old bark and rotten wood; C, M.
Anomodon obtusifolius, Br. and Sch. On rotten bark and wood; C.
Anomodon rostratus, Schimp. On bark (base of tree) and rotten wood; C, S.

Brachythecium acuminatum (Beaur.) Br. and Sch. On decayed trunk and rock; C.
Brachythecium plumosum (Swartz) Br. and Sch. On rock; C, S.
Brachythecium populeum (Hedw.) Br. and Sch. On rock; C.
Brachythecium rutabulum, (L.) Br. and Sch. On rock and rotten wood; C.
Brachythecium salebrosum, (Hoffm.) Br. and Sch. On the ground and rotten wood; C, E, L, M, S.
Brachythecium velutinum, (Hedw.) Br. and Sch. On the ground; C.
Climacium americanum, Brid. On the ground and rotten wood; C, G, L, P, S.
Cylindrothecium brevisetum, (Hook and Wils.) Schimp. On rotten wood; C.
Cylindrothecium cladorrhizans, (Hedw.) Schimp. On ground over rock and rotten wood; C, E, M, P.
Cylindrothecium compressum, (Hedw.) Br. and Sch. At base of old sycamore (sometimes inundated); C.
Cylindrothecium seductrix, (Hedw.) Schimp. On ground over rock and rotten wood; C, E, L, P.
Eurynchium Boscii, (Schwaegr.) Schimp. On the ground and sandrock; C.
Eurynchium hians, (Hedw.) Jaeg. and Sauerb. On the ground and rock; C, L.
Eurynchium piliferum, Br. and Sch. On the ground; C.
Eurynchium strigosum, (Hoffm.) Br. and Sch. On the ground, rock and rotten wood; C.
Homalothecium subcapillatum, Sull and Lesq. On bark; C.
Hylocomium brevirostre, (Ehrh.) Br. and Sch. On the ground; C, L.
Hylocomium rugosum, (Ehrh.) De Not. On the ground; C, S.
Hylocomium splendens, (Hedw.) Br. and Sch. On old wood and ground below pines; C.
Hylocomium triguetum, (L.) Br. and Sch. On the ground; C.
Hypnum chrysophyllum, Brid. On the ground; C, L, Li, O.
Hypnum cristacastrensis, L. On old wood; C, S.
Hypnum cupressiforme, L. On the ground, rock and rotten wood; C, G.
Hypnum cupressiforme longirostre, Br. and Sch. On rotten wood; C, L.
Hypnum curvifolium, Hedw. On the ground and rotten wood; C.
Hypnum cuspidatum, L. On rock; C.
Hypnum Haldanianum, Grev. On the ground, old bark and rotten wood; C, L, S.
Hypnum hispidulum, Brid. On the ground and old wood; C, L, P.
Hypnum imponens, Hedw. On rotten wood; C, L, P, S.
Hypnum molluscum, Hedw. On rock and stony ground; C, L.
Hypnum ochraceum, Turn. On sandrock in creek; C.
Hypnum Patientiæ, Lindl. On the ground; C.
Hypnum pratense, Koch. On the ground; C, Li.
Hypnum Schreberi, Willd. On the ground; C, G, L.

Hypnum uncinatum, Hedw. On rock; C.
Leskea obscura, Hedw. On old bark and rock; C.
Leskea polycarpa, Ehrh. On old bark and wood; C, G.
Leucodon julaceus, Sull. On bark; C, E, O.
Myurella Careyana, Sull. On sandrock; C.
Neckera pennata, Hedw. On old bark; C.
Plagiothecium denticulatum, (L.) Br. and Sch. On the ground and rotten wood; C, E, G, L, P, S.
Plagiothecium denticulatum densum, Br. and Sch. On rock; L.
Plagiothecium Muellerianum, Schimp. On rock; C.
Plagiothecium Sullivantiæ, Schimp. On rock; C, L, S.
Plagiothecium sylvaticum, Br. and Sch. On the ground and rotten wood and leaves; C.
Platygyrium repens, Br. and Sch. On old bark and wood; C. S.
Pylaisia intricata, Br. and Sch. On old bark and wood; C, G, L, S.
Pylaisia velusina, Br. and Sch. On old bark and rotten wood; C, E, L, Pe.
Raphidostegium cylindricarpum, (C. Muell.) De Not. On rock; C.
Raphidostegium demissum, Br. and Sch. On rock; C.
Raphidostegium microcarpum, Muell. On birch bark; C.
Raphidostegium recurvans, (Schwaegr.) Br. and Sch. On rotten wood; C, L.
Rhynchostegium rusciforme, (Neck.) Br. and Sch. On moist rock; C, G, S.
Rhynchostegium serrulatum, (Hedw.) Br. and Sch. On the ground, rock, rotten leaves and wood; C, L, S.
Thelia asprella, (Schimp.) Sull. On old wood; C, E, Pe.
Thelia compacta, Kindberg. On old bark; L.
Thelia hirtella, Sull. On old bark; C.
Thuidium Blandovii, (Web. and Mohr) Br. and Sch. On the ground; G, L, P.
Thuidium delicatulum, Mitt. On rock; L.
Thuidium microphyllum, (Sull.) Best. On old bark and rock; C.
Thuidium minutulum, Hedw. On rock; C.
Thuidium paludosum, (Sull.) Rau. and Harvey. On the ground; G.
Thuidium pygmaeum, Sull. and Lesq. On sandrock; C.
Thuidium recognitum, (Lindl.) On the ground and rotten wood, C,L,S.
Thuidium scitum, Austin. On rotten wood; C.
Thuidium Virginianum, (Brid.) Lindl. On rotten wood; C.

SILURIAN FOSSILS FROM OHIO, WITH NOTES ON RELATED SPECIES FROM OTHER HORIZONS.

Aug. F. Foerste.

The term West Union Cliff was proposed by Prof. Edward Orton in the Report of Progress in 1870, published by the Geological Survey of Ohio in 1871. On page 274 of this report he states that this formation "can be studied to excellent advantage in the typical section of Bisher's dam, where it forms the first line of cliffs in ascending the hill. At this point, it measures 45 feet. To the southward, it is reinforced. It is Dr. Locke's 'Cliff limestone,' of Adams county—to which he assigns a thickness of 89 feet at West Union." It should be noted that although the name of the formation is chosen from West Union, that no description of the West Union section is given; Bisher's dam is regarded as offering the typical section, but no detailed description of the Bisher's dam section is given, beyond the general statement that near Hillsboro it consists of a yellowish, impure magnesian limestone, and that the stone is rather massive than even-bedded in its appearance. Bisher's dam is about a mile south of Hillsboro.

The overlying rock, or Upper Cliff, was called by Orton the Blue Cliff. The best exposures of the Blue Cliff are stated to be at Hillsboro, along the abandoned line of the Cincinnati and Hillsboro railroad, at Academy Hill and at the Trimble quarry at the eastern end of the railroad cut at the eastern margin of the city of Hillsboro. The prevailing color is blue, weathering into various shades of drab and buff. The thickness of the Blue Cliff proper is from 20 to 30 feet; it is underlaid by 5 to 15 feet of blue shale or soapstone, producing a maximum thickness of 30 plus 15, or 45 feet. The basal part of the Blue Cliff proper generally consists of quite massive limestone courses, often more or less crinoidal. The Blue Cliff was incorrectly identified by Prof. Orton with the Springfield dolomite of the more northern counties of Ohio.

Those Niagaran limestones which lie above the Blue Cliff in the Highland county areas, especially at Hillsboro, were correlated by Prof. Orton with the Guelph of New York and

Ontario and the Cedarville dolomite of the more northern counties in Ohio.

The fossils cited by Prof. Orton from the Lower or West Union Cliff are found in a limestone layer occurring from 8 to 10 feet above the base of the formation. This is a continuous and very fossiliferous horizon throughout Highland and Adams counties, in Ohio, and occurs as far south as Martins, in Lewis county, in Kentucky. In the Fauna of the Bisher member of the West Union formation, listed on a following page, all of the fossils cited from Hillsboro, Danville, Sinking Springs, Crooked Creek, Peebles, West Union and Martins came from this horizon, while the remainder came from approximately the same zone. Fossils from the James Sanderson locality are here listed as from Danville.

Among the fossils cited by Prof. Orton from the Upper or Blue Cliff are *Halysites*, *Favosites* and Zaphrentid corals identified by him as *Streptelasma*. The spherical concretions stated to be common in Marshal township, in Highland county, unquestionably are a form of Stromatoporoid.

The rock identified as Guelph or Cedarville contains in the Hillsboro area a considerable abundance of *Pentamerus oblongus*. *Megalomus canadensis*, *Trimerella acuminata*, *Trimerella grandis*, and *Trimerella ohioensis* are listed by Prof. Orton from this rock. In the Hillsboro area, according to Prof. Orton, *Megalomus canadensis* and *Pentamerus oblongus* occur more or less associated, although in very unequal numbers. Farther eastward and southward, however, in Ohio, *Megalomus* and *Trimerella* occur in strata *above* the *Pentamerus* containing layers, whenever the latter occur, which is rarely the case.

While the various observations of Prof. Orton on the faunas of the Lower Cliff, Blue Cliff, and Guelph formations of Highland county and of the neighboring Adams county are confirmed by later investigations, they are not sufficiently detailed to serve to correlate the southern Ohio strata here mentioned with those occurring elsewhere. To supply the necessity for more detailed information, at least in part, the following lists of the fossils found in the Bisher and Lilley members are provided, accompanied by a description of some of the less known forms. The Bisher member here corresponds to the Lower or West Union Cliff of Orton, while the Lilley member corresponds to the Upper or Blue Cliff.

Fauna of Bisher Member of West Union Formation.

Cornulites clintoni Hall; Crooked Creek, West Union, Glen Springs.
Chasmatopora angulata (Hall); West Union.
Clathropora frondosa Hall; West Union, Glen Springs.
Pholidops subelliptica Savage; Sinking Springs.
Orthis flabellites Foerste; Port William.
Dalmanella elegantula (Dalman); Port William, Peebles, Harin Hill.
Rhipidomella hybrida (Sowerby); Port William, Hillsboro, Danville.
Rhipidomella magnicardinalis Foerste (=hybrida?); Peebles, West Union, Glen Springs.
Platystrophia daytonensis Foerste; Port William.
Platystrophia pauciplicata Foerste; West Union.
Leptaena rhomboidalis (Wilckens); Port William, Hillsboro, Danville, Crooked Creek, West Union, Martins, Harin Hill, Glen Springs.
Plectambonites transversalis (Wahlenberg); Danville.
Schuchertella confertus Foerste; Port William, Danville, Martins.
Schuchertella prosseri Foerste; Port William, Hillsboro, Danville, Peebles.
Stropheodonta (*Brachyprion*) *plana* Foerste; Port William, Danville, Sinking Springs, Crooked Creek, Peebles, West Union, Martins, Harin Hill.
Stropheodonta (*Brachyprion*) *plana* Foerste, broad variety; Danville.
Camarotoechia acinus subrhomboidea Foerste; Danville, Martins.
Camarotoechia neglecta (Hall); Peebles, West Union.
Camarotoechia pisa (Hall and Whitfield); Danville, Peebles, Martins.
Camarotoechia roadsi Foerste; Hillsboro, Crooked Creek.
Camarotoechia cf. stricklandi; Port William, Peebles.
Rhynchotreta cuneata americana (Hall); Peebles, West Union, Carrs, Glen Springs.
Atrypa reticularis elongata Foerste; Port William, Hillsboro, Danville, West Union.
Atrypa rugosa Hall; West Union, Glen Springs.
Trematospira camura pauciplicata Foerste (=Atrypa?); West Union.
Spirifer eudora Hall; West Union.
Spirifer harinensis Foerste; Harin Hill.
Spirifer nanus Foerste; West Union, Glen Springs.
Spirifer niagarensis (Conrad.) (=repertus Foerste?); Port William, Danville, Peebles, West Union, Harin Hill.
Spirifer radiatus Sowerby; Port William, Hillsboro, Danville, West Union, Martins.
Spirifer radiatus obsoletus Foerste; Glen Springs.
Cyrtia myrtia (Billings); West Union.
Whitfieldella cylindrica Hall; Port William, Hillsboro, Danville.
Whitfieldella, form from which *cylindrica* is a derivative; Peebles, West Union, Harin Hill, Glen Springs.
Diaphorostoma cliftonense Foerste; Martins.
Diaphorostoma niagarense (Hall); Port William, Hillsboro, Danville, Peebles, West Union.

Platyceras angulatum (Hall); Peebles.
Illaenus depressus Foerste; Glen Springs, Martins.
Bumastus ioxus (Hall); Danville.
Cyphaspis sp.; West Union.
Encrinurus sp.; West Union.
Calymene niagarensis Hall; Martins, Harin Hill.
Trimerus delphinocephalus Green; Sinking Springs, Crooked Creek, Peebles, West Union, Martins.
Cheirurus niagarensis (Hall); West Union.
Dalmanites limulurus brevicaudatus Foerste; Hillsboro, Danville, Sinking Springs, Crooked Creek, Peebles, West Union, Martins.

Fauna of Lilley Member of West Union Formation.

QUARRY WITHIN EASTERN LIMITS OF HILLSBORO, OHIO.

Holophragma calceoloides Lindstrom.
Zaphrentis digoniata Foerste.
Cyathophyllum roadsi Foerste.
Acervularia paveyi Foerste.
Strombodes striatus (D'Orbigny).
Plasmopora follis Edwards and Haime.
Coenites verticillatus (Winchell and Marcy).
Halysites labrynthicus (Goldfuss).
Stromatoporid.
Rhipidomella hybrida (Sowerby).
Leptaena rhomboidalis (Wilckens).
Stropheodonta (*Brachyprion*) *newsomensis* Foerste.
Anastrophia internascens Hall.
Camarotoechia indianensis (Hall).
Camarotoechia cf. neglecta (Hall).
Rhynchotreta cuneata americana Hall.
Atrypa reticularis hillsboroensis Foerste.
Spirifer crispus (Hisinger).
Poleumita paveyi Foerste.
Poleumita prosseri Foerste.
Trochonema fatuum (Hall).
Diaphorostoma hillsboroensis Foerste.
Proetus collinodosus Foerste.
Encrinurus cf. ornatus (Hall and Whitfield).
Calymene cf. vogdesi Foerste.
Dalmanites brevigladiolus Foerste.

CROOKED CREEK, NEARLY TWO MILES NORTH OF LOCUST GROVE, OHIO.

Cyathophyllum radicula Rominger.
Omphyma cf. verrucosa Rafinesque and Clifford.
Cystiphyllum niagarense Hall.
Heliolites subtubulatus (McCoy).
Favosites spinigerus Hall.
Striatopora small celled.

In case of the fauna listed from the Bisher member, all of the fossils listed from Hillsboro, Danville, Sinking Springs, Crooked Creek, Peebles, West Union and Martins came from the richly fossiliferous layer occurring about 8 to 10 feet above the base of this member. The fossils listed from Port William apparently come from about the same horizon, as far as may be judged from the fossils present. Those listed from Carr's, Harin Hill and Glen Springs at least belong to the Bisher member. The exact location of the various exposures here cited is as follows:

Half a mile west of Port William, several hundred yards south of the bridge, an exposure of the Bisher member occurs in the creek. A mile southeast of Hillsboro, several hundred yards northeast of Bisher dam bridge, typical exposures of the Bisher member occur along the hill front, and continue at various intervals as far as the deep valley southeast of the built-up part of Hillsboro. About a mile north of Danville, on the east side of the Hillsboro pike, is the James Sanderson farm exposure mentioned by Prof. Orton. Half a mile west of the southern end of Sinking Springs, the Bisher member is exposed on the western side of Baker Fork. North of Crooked Creek, a mile and a half north of Locust Grove, the Bisher member is exposed in a quarry west of the pike. Half a mile west of Peebles, along the railroad, a large quarry exposes the full thickness of this member. In the southeastern corner of West Union, on the Beasley Fork road, a small roadside quarry exposes the basal half of the Bisher member. The remainder of the section is exposed in the open fields eastward. The outcrop at Carrs is about half a mile south of the railroad station, which is about 8 miles west of Vanceburg, in Kentucky. The outcrop is formed by the cut of the road across the hill ridge. Martins is located about 2 miles southwest of the road cut. The Bisher member forms the upper part of the knob northwest of the Martin store. Harin Hill is about 4 or 5 miles southwest of Martins; the exposure is made by the road from Valley to Ribot, which cuts across the hill. Glen Springs is 4 or 5 miles south of Harin Hill, on the road from Valley to Esculapia Springs. Carrs, Martins, Harin Hill and Glen Springs are all in Lewis county, Kentucky.

In case of the fossils listed from the Lilley member, all cited from the quarry within the eastern limits of Hillsboro occur either in the 2-foot clay shale which overlies the typical Upper or Blue Cliff rock, or in the immediately underlying parts of the Upper or Blue Cliff rock, within 5 feet of the base of the overlying clay shale. This clay shale is referred to in the accompanying pages as the *Holophragma* zone, but *Holophragma* ranges downward into the underlying Upper or Blue Cliff rock. At the exposure immediately north of Crooked creek, on the east side of the pike from Locust Grove to Sinking Springs, at highest road level, exposures occur which are regarded as stratigraphically equivalent to the top of the Upper or Blue Cliff rock, as exposed at Hillsboro.

It should be emphasized that in these lists are included only those fossils occurring in the lower part of the Bisher member and in the upper part of the Lilley member. The fauna of the intermediate strata has not been well worked out.

The Bisher member includes all of the Lower or West Union Cliff of Orton. The Lilley member includes the massive limestone layers which form the typical Upper or Blue Cliff of Orton. The intermediate blue shale or soapstone was included by Orton in the basal part of his Upper or Blue Cliff formation. In the vicinity of Hillsboro it is practically unfossiliferous. Such few fossils as may be identified in this intermediate horizon appear to belong to the lower or Bisher fauna rather than to the upper or Lilley fauna. The highest strata exposed in the southeastern part of West Union may correspond to these upper more shaly members. Such fossils as they contain appear more nearly related to the Bisher fauna than to the Lilley fauna. For the present, therefore, the base of the Lilley member in the Hillsboro section, is drawn at the base of the bluish, apparently argillaceous limestone which lies immediately beneath the clay shale containing *Holophragma calceoloides* in abundance. At the Zink or Corporation quarry this limestone has a thickness of 14 feet, and at the Trimble quarry its thickness is nearer 21 feet. Beneath this more massive limestone occurs a thinner-bedded, more or less laminated, and frequently cherty limestone, with few fossils, beneath which occurs the blue shale or soapstone mentioned before. No trace of the characteristic Lilley fauna has been found so far in the cherty limestone layers which occur beneath the more massive, blue, apparently argillaceous limestone, and, therefore, the base of the more massive blue limestone is regarded as forming the base of the Lilley member.

No trace of the Bisher fauna has been found as yet north of Port William, at the northern margin of Clinton county, in Ohio. Much higher strata occur at Leesburg, in the northern part of Highland county, but none of the characteristic fossils of the Lilley member have been identified at this locality, so that, at present, the Lilley fauna appears of very limited geographical extent.

The faunas of the Niagaran strata of Highland and Adams counties, in southern Ohio, have little in common with those of the Niagaran strata of southern Indiana. On that account any attempt at correlation is likely to prove of little value.

The Bisher fauna contains *Spirifer niagarensis* and *Bumastus ioxus* in the same form as in the Osgood formation of southern Indiana, and the *Whitfieldella cylindrica* of the Bisher fauna is represented in the Osgood fauna of southern Indiana by a similar, though smaller form. In the Bisher exposure in the quarry along the Beasley Fork road, in the southeastern part of West Union, a single plate occurred containing the very characteristic double pairs of pores found in *Trematocystis* and other cystids incorrectly described by S. A. Miller from Indiana as *Holocystites*. These few fossils are scarcely enough to correlate the Bisher member of southern Ohio with the Osgood formation of southern Indiana; however, this is the only correlation which the present evidence seems to suggest. Immediately overlying the argillaceous strata at the base of the section on the creek east of Leesburg, in the northern part of Highland county, occur *Stephanocrinus gemmiformis* and *St. hammelli*, the second of which is characteristic of the Osgood formation in southern Indiana, but the precise correlation of the Leesburg stratum containing these specimens of *Stephanocrinus* with those exposed in the Hillsboro section is still in doubt. If they are of Bisher age, they would assist in correlating the Bisher strata with those of Osgood age.

In the fauna of the Lilley member, *Cyathophyllum radicula*, *Omphyma* cf. *verrucosa*, *Strombodes striatus*, *Cystiphyllum niagarense*, *Plasmopora follis* and *Coenites verticellatus* suggest relationship with the Louisville limestone of southern Indiana and the adjacent part of Kentucky. *Trochonema fatuum*, from the Racine of Wisconsin, is known also from the Guelph of New York and the Louisville of Kentucky. *Poleumita paveyi* and *Poleumita prosseri* are both related to Guelph species. *Dal-*

manites brevigladiolus is most nearly related to *Dalmanites platycaudatus* from the Racine of Illinois. Provisionally, the Lilley member is correlated with the Louisville member of Southern Indiana and the adjacent parts of Kentucky.

An approximate correlation of the Bisher member with Niagaran strata in New York state is made possible by the fact that the upper part of the Crab Orchard shale, which lies immediately beneath the Bisher member, contains *Liocalymene clintoni*, *Beyrichia lata*, and other fossils occurring in the middle part of the typical Clinton section of New York. In the overlying Irondequoit limestone, however, at the top of the Clinton of New York, occur numerous species found also in the Bisher member, including *Cornulites clintoni*, *Orthis flabellites*, *Spirifer radiatus*, *Rhynchotreta americana*, *Whitfieldella cylindrica*, *Anastrophia interplicata*, *Stephanocrinus gemmiformis*, *Trimerus delphinocephalus* and *Bumastus ioxus*. Provisionally, therefore, the Bisher member is correlated with the Irondequoit limestone of New York.

The coral element in the Lilley fauna suggests correlation of the Lilley member with the western extension of the Lockport dolomite, as it is seen on Manitoulin and Drummond islands, in the northern part of Lake Huron. Such fossils as *Cyathophyllum radicula*, *Omphyma verrucosa*, and *Strombodes striatus* are characteristic of this western phase of the Lockport.

If the Bisher fauna be correlated with the Osgood of Indiana and the Irondequoit of New York, and if the Lilley fauna be correlated with the Louisville of Indiana and Kentucky and with the Lockport of southern Ontario, then it is possible that a gap in time exists between the two, although this gap may be filled partially by that part of the fauna of the Bisher member which exists in its upper layers, this fauna not having been sufficiently studied so far to determine the question.

In Ohio, *Strombodes striatus* has been found also in the Springfield limestone, at the base of the excavation for the Lockington dam, four miles north of Piqua, Ohio.

The relationship of the Lilley fauna appears to be with the overlying Guelph, rather than with the underlying Bisher fauna.

It is believed that eventually it will be found that the line of separation between the Bisher and Lilley members of the Niagaran must be drawn considerably higher than the line between the West Union Cliff and the Upper or Blue Cliff, as drawn by Orton at Hillsboro. Moreover, if Hillsboro is to be considered as the type area for the Lower Cliff of Orton, the latter oughtto receive a name taken from the Hillsboro area. Therefore, the name Bisher has been chosen. However, at any distance from the Hillsboro area, it has proved so rarely possible to discriminate the Bisher and Lilley members, if indeed the latter is present, that a collective term seems desirable. For this service the term West Union, used by Orton, has been regarded as serviceable and as much more in keeping with the exposures at West Union, Ohio, where no trace of the Lilley member can be identified.

Dinobolus conradi (Hall).

Plate XVII, Fig. 6.

A cast of the interior of the pedicel valve, found in the Cedarville dolomite, in the most eastern of the Mills quarries, southwest of Springfield, Ohio, is here figured. This species was described originally from the Leclaire limestone at Leclaire, Iowa, and from the Racine limestone at Racine, Wisconsin. It makes its appearance in Wisconsin as early as the Lower Coral beds, in the lower part of the Waukesha beds, which lie beneath the Racine limestone. In Ohio this species has been known hitherto only from the single individual, from the Niagaran at Crawford, in Wyandot county, figured by Hall and Whitfield in the second volume of the Palæontology of Ohio, in 1875. This locality lies about 70 miles north of Springfield; here it is associated with *Megalomus canadensis* and casts of *Trimerella*, suggesting an age corresponding with that of the *Megalomus* beds of Highland and Adams counties, in southern Ohio.

Schuchertella prosseri Sp. nov.

Plate XVI, Figs. 1 A-E.

At the *Whitfieldella* horizon, nine feet above the base of the Lower of Bisher member of the West Union formation, about a mile southeast of Hillsboro, Ohio, along the hill-front northeast of the Bisher dam bridge, a large species of *Schuchertella* is common. Occasional specimens occur also near Danville, and a half a mile west of Port William, Ohio. Among described species, this lower West Union species resembles most the *Schuchertella tenuis* described by Hall from the Waldron shale of Indiana.

The pedicel valves are distinctly concave, the beak being slightly elevated above the adjacent parts of the valve. The brachial valve is convex, with the greatest convexity anterior to the center of the valve. The sides of the shell converge moderately posteriorly, so that the hinge-line is shorter than the greatest width of the shell, but there is no conspicuous rounding of the postero-lateral angles. Contrasted with *Schuchertella tenuis*, the shell is much more elongate, but the amount of elongation varies considerably in different individuals. While in the more moderately elongated shells the anterior outline may be broadly and regularly convex, in the more strongly elongated shells the convexity of the anterior outline increases toward the median line, producing sometimes a subtriangular appearance. Associated with this subtriangular appearance the concavity of the pedicel valve is most pronounced along the median line, and there is a corresponding accentuation of the convexity of the brachial valve, especially anteriorly. In the most elongated specimen at hand the greatest width of the shell was near the hinge-line, and equalled 50 millimeters; at mid-length, the width equalled 46 millimeters; ten millimeters from the front the width equalled 34 millimeters; the entire length of the shell was 50 millimeters. By comparing these dimensions with those indicated by Figures 1A and 1B on the accompanying plate, the amount of divergence of this outline from the normal type may be noted. It is in these more elongate shells that the concavity of the pedicel valve is most pronounced reaching in one case 6 millimeters. The greatest convexity noted so far is that shown by the specimen represented by Figures 1A and 1C, on Plate XVI; in this case it equals 16 millimeters, while in other specimens of equal length the convexity may not exceed 9 millimeters. The radiating striæ tend to be subequal in size, excepting of course at their point of insertion. They vary in number from 7 to 10 in a width of 5 millimeters.

The interior of the pedicel valve is exposed frequently, but the clearest indications of the outlines of the muscular area are presented by the casts presented by the matrix filling these interiors. In outline this muscular area is almost circular and is distinctly delimited except near the median line anteriorly. Posterior to the center of this muscular area there is a small oblong space locating the position of the posterior adductors. A median line of elevation, often bordered laterally by shallow lines of depression, extends across this oblong space. In occasional specimens the remainder of the muscular area is marked by more or less irregularity branching radiating lines of elevation. The dental lamellæ are short and diverge at angles of about 105 degrees.

The interior of the brachial valve presents crural ridges, about 6 mm. long, diverging at an angle of about 140 degrees, and a low, broad, median elevation of about the same length. No definite muscular area can be detected.

This species is an excellent illustration of the great variation in outline, length, and general convexity which can occur in a single species. Fortunately, in the present case, numerous specimens from the same locality and horizon are present, preventing the discrimination of these forms into separate so-called species. In the absence of abundant material the more extreme forms might appear distinct enough to be separated at least as varieties, if not as species.

Stropheodonta (Brachyprion) plana Foerste.

Plate XVI, Figs. 2 A, B.

1909. *Stropheodonta* (*Brachyprion*) *planus* Foerste, Cincinnati Soc. Nat. Hist., Jour., vol. 21, P. 22, pl. 1, figs. 13 A-C; pl. 2, figs. 11 A, B.

At the *Whitfieldella cylindrica* horizon, in the Lower or Bisher member of the West Union formation at Hillsboro and Danville, Ohio, several specimens of *Stropheodonta* occur which differ sufficiently among each other to suggest the presence of more than one species, but the material at hand does not permit of definite diagnosis. The most obvious difference is that some specimens appear shorter and broader than others, the ratio of length to width in the former specimens being as 7 to 10, in contrast with the ratio of 8 to 10 in the latter; but, apparently, specimens of intermediate length occur also. Some of the specimens are more convex than others, and in these more convex specimens the radiating striations are subequal in size, while in several of the flatter specimens the radiating striations are finer and every fourth one tends to be more prominent; however, there is considerable variation in convexity and variation in the character of the radiating striations, and such as those noted above are known to be not uncommon among the Strophomenidæ. For the present, therefore, the specimen here figured will be referred to the species already described.

Compared with other shorter forms from the same locality and horizon, it is more convex and its radiating striations are more nearly subequal in size. The shell material is exfoliated, so as to present an almost perfect cast of the interior of the pedicel valve. Postero-laterally the muscular area is clearly delimited, the sides making an angle of 80 degrees. Posteriorly, within this area, there are two oblong shallow depressions, separated by a low, sharp, narrow ridge, and the former are interpreted as the anterior adductor scars. The anterior margin of the muscular area is not distinctly delimited in this specimen. Between the postero-lateral margins of the muscular area and the adjacent parts of the hinge-area, there are numerous sharply elevated granules, characterizing the so-called ovarian spaces. (Plate XVI, fig. 2.)

In an associated brachial valve, in which the ratio of length to width is as 77 to 100, almost the entire interior of the valve is minutely granulose, the granules tending toward linear arrangement along the crests of the fine radiating lines which correspond to the grooves between the radiating striæ characterizing the exterior of the shell. From the bilobed cardinal process short thickened lines of elevation extend obliquely forward, limiting the postero-lateral outlines of the muscular area. A short, low, but broad line of elevation also extends from the cardinal process straight forward, dividing the muscular area.

In our present state of knowledge of the Stropheodontoid shells of the Clinton group of New York, it is scarcely worth while to attempt to correlate any of the West Union forms with the latter. To me, the *Leptaena obscura*, from the upper ore beds of the typical Clinton, appears to be a Schuchertella. I strongly suspect that *Stropheodonta prisca* is identical with *Leptaena orthididea*, being associated with the latter in the iron beds of the typical Clinton. Both belong to the subgenus *Brachyprion*. *Leptaena corrugata*, another Stropheodontoid, is said to be most abundant in the upper green shale of the Clinton and in the Pentamerus limestone member beneath. *Leptaena profunda*, another Stropheodontoid, was described from the Irondequoit limestone. From among these species, the West Union specimens appear most nearly related to *Stropheodonta orthididea*.

Stropheodonta (Brachyprion) newsomensis Foerste.

Plate XVIII, Figs. 1 A-C.

In the *Holophragma* zone, at the top of the Upper or Lilley member of the West Union formation, in the Zink or Corporation quarry, within the eastern limits of Hillsboro, Ohio, a form of *Brachyprion*, here figured, is not uncommon. It belongs to the more elongated forms of this genus.

Ratio of length to width 82-85 per cent. About 7 or 8 striæ occupy a width of 2 millimeters. The muscular area of the pedicel valve is bounded laterally by diagonal extensions of the dental lamellæ. There is a median septal ridge terminating posteriorly in a small, triangular callosity, with two of its angles directed diagonally toward the front. Near the foramen, the lower part of the hinge area is vertically striated, and beyond the striated area the interior of the shell, beneath the hinge area, is thickened by a linear callous growth. The cardinal process of the brachial valve consists of two lobes, grooved along the top, forming approximately a right angle with each other. From the base of these lobes two low, broad callosities, bordering the sides of the posterior part of the muscular area of this valve, can be traced diagonally forward for a distance of three or four millimeters. From the bases of the same lobes of the cardinal process, two additional very low callosities converge toward the front so as to meet within four millimeters from the hinge line. Two low diagonal lines separate the posterior part of the muscular area from the anterior parts, and a low median line often may be noted in the intermediate area. In both valves, the interiors are finely granulated. The granules of the brachial valve appear somewhat coarser, especially posteriorly, on each side of the muscular area. In both valves the granules tend to be arranged along the crests of the lines which evidently correspond to the grooves between the striæ appearing on the exterior of the shells.

No interiors of typical *Brachyprion newsomensis*, from the Waldron of Tennessee, are at hand for direct comparison. The exteriors appear similar. (Bull. Sci. Lab. Denison Univ., 14, 1909, p. 87, pl. 4, fig. 67.)

Camarotoechia indianensis (Hall).

Plate XVII, Figs. 4 A-C.

1863. *Rhynchonella indianensis* Hall, Trans. Albany Inst., vol. 4. p. 215.

This familiar Waldron species is characterized by the presence of a low fold supporting four plications, and a shallow sinus containing three plications. All of the plications tend to be low and rounded, but are distinct as far as the beak. The general form is rhomboid-ovate. At the anterior margin of the shell the slope of the sinus meets that of the fold at a right angle, producing an oblong outline on lateral view.

Shells having the same general characteristics occur in the *Holophragma* zone at the top of the upper or Lilley member of the West Union formation, at the Zink or Corporation quarry, within the eastern limits of Hillsboro, Ohio.

Camarotoechia cf. **neglecta** (Hall).

Plate XVII, Figs. 5 A-C.

The type of *Camarotoechia neglecta* is a Clinton form, from the Reynale's limestone of New York. With this Clinton form it is customary to identify certain Niagran forms which may eventually prove to belong to a distinct species.

The Niagaran forms differ from *Camarotoechia indianensis* in their smaller size, higher fold and deeper sinus, distinctly more angular plications, and a somewhat more triangular form. Frequently the depressed area within the sinus meets the area on the fold of the opposite valve at an angle which is more acute than a right angle.

At the *Holophragma* zone, in the eastern part of Hillsboro, Ohio, occasional specimens of *Camarotoechia* are found which resemble *Camarotoechia neglecta* in their more angular plication, their higher fold and deeper sinus. They may, however, be merely variations of the species identified above from the same locality as *Camarotoechia indianensis*.

Rhynchotreta cuneata americana Hall.

Plate XVI, Figs. 3 A, B; Plate XVII, Fig. 3.

In typical *Rhynchotreta americana*, from the Waldron shales of Indiana, the two median plications on the fold of the brachial valve are wider and more conspicuously elevated than the two lateral plications on this fold; moreover, the anterior part of the shell is widened laterally so strongly that the postero-lateral outline becomes distinctly concave in mature individuals.

At the *Whitfieldella* horizon, nine feet above the base of the Lower or Bisher member of the West Union formation, in the eastern part of Hillsboro, Ohio, the two lateral plications on the median fold of *Rhynchotreta cuneata americana* (Plate XVI, Figs. 3, A, B), are only moderately below the two median plications on this fold and all four plications are of about the same width; moreover, the rate of widening of the shell anteriorly is more even, so that the postero-lateral margins are nearly straight. However, in specimens obtained from about the same horizon, at West Union, Ohio, the two median plications on the fold of the brachial valve are conspicuously elevated above the two lateral plications on this fold, as in typical *Rhynchotreta cuneata americana*, so that it does not seem possible to distinguish the forms from the Lower part of the West Union formation from the typical forms in the Waldron shale unless it be assumed that two forms are present in the West Union bed, an assumption which appears premature in our present meager information regarding the range of variation among the specimens occurring in the West Union formation.

Rhynchotreta cuneata americana is abundant at some localities in the upper part of the West Union formation, associated with numerous specimens of a small-celled species of *Favosites*. The specimen here figured (Plate XVII, Fig. 3), was obtained in the upper part of the exposures in the road-cut, south of Carr's station, in Lewis county, Kentucky. . It presents a cast of the interior of the brachial valve, with its median septum, also a cast of the deltidial cavity.

Atrypa reticularis elongata, var. nov.

Plate XVI, Figs. 4 A-C.

In his report on Greene County, in the second volume of the Geology of Ohio, published in 1874, on page 671, Prof. Edward Orton stated regarding the West Union Cliff rock: "It is to be identified principally by its containing a fossil known as an elongated form of *Atrypa reticularis*. On the ground of its occurrence in Ohio strata, a distinct designation ought certainly to be given to this form, for it is never found above the horizon of the West Union cliff." Although in my opinion the West Union formation does not occur in Greene county, and the rock thus identified there should be referred to the Euphemia dolomite, there is an *Atrypa* of an elongate form which may be regarded as characteristic of the West Union formation. This *Atrypa* is most abundant in the *Whitfieldella cylindrica* zone, nine feet above the base of the Lower or Bisher member of the West Union formation, in the southeastern part of Hillsboro, Ohio, but specimens occur also in the vicinity of Danville and of Port William, at the same horizon. In general form this variety resembles most closely the specimen figured by Hall and Clarke (Pal. New York, vol. 8, pt. 2, 1894, pl. 55, figs. 3, 4) from the shaly limestone of the Lower Helderberg group, near Clarksville, New York.

The amount of elongation of the elongate variety of Atrypa which occurs in the Bisher member varies greatly in different specimens, but is always seen best when the specimen is viewed from the same side as the pedicel valve. In full-grown specimens the beak of the pedicel valve rises rather strongly above the beak of the brachial valve. Both valves are strongly convex. The anterior part of the pedicel valve tends to be slightly flattened and that of the brachial valve to be slightly elevated so that the anterior margin of the shell is slightly nasute. The radiating plications are more narrow than in *Atrypa reticularis newsomensis*, from the Waldron shale of Tennessee, Kentucky and Indiana.

Atrypa reticularis hillsboroensis, Var. nov.

Plate XVII, Figs. 1 A-D.

In the *Holophragma* zone, at the top of the upper or Lilley member of the West Union formation, in the Zink or Corporation quarry, within the eastern limits of Hillsboro, Ohio, there is a small form of *Atrypa*. This variety resembles most closely the variety *Atrypa reticularis newsomensis*, from the Waldron clay member of the Niagaran. It differs chiefly in its smaller size and in the more crowded condition of the plications.

Rarely exceeding 17 mm. in length. Anteriorly the pedicel valve tends to be marked by a distinct sinus, while the corresponding part of the brachial valve is elevated into a fold. Frequently the line of junction between the two valves, when viewed directly from in front, is strongly sinuate. Most of the specimens show concentric lines of growth, some of which tend to become conspicuous, although on some of the specimens the lines of growth are inconspicuous over the middle and posterior parts of the shell. About 6 plications occupy a width of 5 millimeters.

Spirifer niagarensis (Conrad).

Plate XVI, Figs. 7 A, B.

Spirifer niagarensis Hall, Pal. New York, 1852, pl. 54, figs. 5 a-t.
Spirifer repertus Foerste, Cincinnati Soc. Nat. Hist. Jour., vol. 21, 1909, p. 16, pl. 1, figs. 14 A, B: pl. 2, fig. 5.

Spirifer repertus was described from the lower part of the West Union formation, at Harin Hill, about eight miles southwest of Vanceburg, in Lewis county, Kentucky. Larger specimens of apparently the same species, obtained from the *Whitfieldella* horizon, in the Lower or Bisher member of the West Union formation, about nine feet above the base of the latter, do not appear to differ from typical specimens of *Spirifer niagarensis*, as found in the Rochester shale of New York. In Indiana, this species occurs in the Osgood formation.

Whitfieldella cylindrica (Hall).

Plate XVI, Figs. 6 A-C.

1852. *Atrypa cylindrica* Hall, Pal. New York, vol. 2, p. 76. pl. 24, figs. 2 a-h.
1873. *Meristella (?Meristina) cylindrica* Meek, Pal. Ohio, vol. 1, p. 180, pl. 15, figs. 2 a-d.
1893. *Whitfieldella cylindrica* Hall and Clarke, vol. 8, pt. 2, p. 60, pl. 40, figs. 16-22.

Whitfieldella cylindrica was described from the Irondequoit limestone which forms an upper member of the Clinton formation of New York. About nine feet above the base of the Lower or Bisher member of the West Union formation, in the vicinity of Hillsboro and Danville, Ohio, a form occurs which evidently is closely related, but which attains a larger size, frequently equalling 35 millimeters.

Specimens from the West Union formation which are no larger than those from the Irondequoit limestone agree with the latter in general appearance, but specimens which are larger than the latter tend to be more distinctly flattened along the anterior half of the pedicel valve. In specimens from both horizons there is a tendency toward a narrow median line of depression along the anterior half or two-thirds of this valve. Corresponding to the broad flattening of the pedicel valve there is a broad, but slight increase in convexity of the median parts of the brachial valve anteriorly in many of the specimens from the West Union formation. Some of the specimens from the Hillsboro and Danville areas are strongly flattened laterally, especially posteriorly, this flattening attracts most attention when the shell is viewed from the pedicel valve side of the shell. These laterally flattened shells evidently are only individual variations from the much more abundant shells in which the lateral outline is more ovate. In occasional specimens the lateral boundaries of the flattened anterior areas of the pedicel valve are slightly elevated and are bounded on their inner sides by very shallow lines of depression. In such cases, if the median line of depression be present, the anterior half of this valve appears marked by four, rather faint, low plications, somewhat as illustrated by Hall and Clarke.

The laterally compressed individuals, such as those illustrated by Meek and by Hall and Clarke, are most abundant in the vicinity of Hillsboro and Danville, Ohio, where they form only a moderate percentage of the more normal broader forms. Half a mile west of Port William, Ohio, on the road to Lumberton, a quarter of a mile south of the bridge, many of the specimens are rather broadly ovate, but a few of the laterally compressed forms occur also. The species is widely distributed in the lower part of the West Union formation in southern Ohio, but usually without any evidence of lateral compression, which seems to be a local feature.

Specimens closely resembling typical *Whitfieldella cylindrica* from the Irondequoit limestone of New York, both in size and form, occur also in the Osgood formation of Indiana, especially in the area southwest of Versailles, in Ripley county. Here also the narrower specimens are exceptional and are associated with broader, ovate forms, the latter occurring in much larger numbers.

Poleumita prosseri Sp. nov.

Plate XVII, Figs. 8 A-C.

Spire depressed, with the apex rising but slightly above the margin of the outer whorl. Whorls five or six; convexity of upper side of body whorl slightly depressed; convexity of lower side broader and distinctly flattened; umbilicus relatively small and shallow. On the upper side of the body whorl, half way between the suture and the periphery, there is a distinct but low revolving ridge. Along the periphery there is a similar, but much fainter revolving ridge. Between the two ridges just described occur two more, so as to form a series following each other at shorter intervals in a downward direction. Sometimes a fifth revolving ridge may be faintly recognized just below the peripheral line. At the ridges, the transverse striæ bend slightly backward and at the same time rise in prominence, thus producing the appearance of a revolving ridge. Six or seven transverse striæ occur in a length of 2 millimeters. The largest specimen discovered so far was 28 mm. in diameter, and had a body whorl 9 mm. in height; the thickness of the shell at the aperture equalled one millimeter.

LOCALITY AND POSITION: In the *Holophragma* zone of the upper or Lilley member at the Zink or Corporation quarry, within the eastern limits of Hillsboro, Ohio. Named in honor of Prof. Charles S. Prosser, who made a special study of the Hillsboro section.

REMARKS: In general appearance this species most nearly resembles *Poleumita crenulata* (Whiteaves), from the Guelph of Canada and New York. It differs greatly, however, in its much more depressed spire. Compared with such species as *Poleumita durhamensis* (Whiteaves), the revolving ridges are much less prominent.

Poleumita paveyi Sp. nov.

Plate XVII, Figs. 9 A-C.

Spire low, but with the apex rising distinctly above the level of the outer whorl; in the largest specimen at hand, about 22 mm. in diameter, the apex of the spire rises at least 4 mm. above the outer whorl. Whorls five or six; the convexity of the outer or body whorl is more or less obliquely depressed; the convexity of the lower side of the body whorl is moderate; and the umbilicus is relatively shallow. Between the upper suture of the body whorl and its periphery there are 11 or 12 rather strong revolving ridges, equally spaced. Below the peripheral line there are about 6 additional revolving ridges, the inner of which bounds the comparatively smooth umbilicus. In the larger specimen, here described, the revolving ridges are slightly less than half a millimeter in width and are slightly more than half a millimeter apart. The revolving ridges are crossed by conspicuous transverse striæ, of which 5 or 6 occur in a length of two millimeters, toward the aperture of the body whorl. Where the transverse striæ cross the revolving ridges they are bent conspicuously backward.

LOCALITY AND POSITION: In the *Holophragma* zone, at the top of the upper or Lilley member of the West Union formation, at the Zink or Corporation quarry, within the eastern limits of Hillsboro, Ohio. Named in honor of Henry Pavey, who was much interested in the geology of the area surrounding Hillsboro.

REMARKS: Compared with *Poleumita scamnata* Clarke and Ruedemann, from the Guelph of New York, both the revolving ridges and the transverse striae are coarser. In *Poleumita huntingtonensis* Kindle and Breger the spire is much higher and there is nothing known of the transverse striae. In *Poleumita plana* Kindle and Breger the revolving ridges are less numerous, are more widely spaced and the top of the spire is more flattened, being actually depressed in some specimens.

Trochonema fatuum (Hall).

Plate XVII, Figs. 7 A, B.

1868. 20th Rep. New York State Cab. Nat. Hist., p. 345, pl. 15, figs. 7, 8.

An unknown species of *Trochonema* occurs in the *Holophragma* zone, at the top of the upper or Lilley member of the West Union formation, at the Zink or Corporation quarry, within the eastern limits of Hillsboro, Ohio. The general resemblance of the Hillsboro specimens to *Trochonema fatuum*, from the Racine of Wisconsin, is considerable, although in size they are much smaller. They agree in the following features:

Characterized by the broadly concave peripheral area extending longitudinally along the whorls, bounded above and below by an acute and fairly prominent ridge. From the upper ridge to the upper suture of the whorl the slope is gently concave. From the lower ridge toward the umbilicus the curvature is rather evenly convex.

Diaphorostoma hillsboroensis Sp. nov.

Plate XVII, Figs. 10 A-D.

The inner margin of the aperture apparently is thin, as in *Diaphorostoma*. Species small, none of the specimens exceeding 16 mm. in diameter. Whorls about four; the apex of the shell rising but moderately above the outer whorl. The chief characteristic feature consists in the presence of low revolving lines, which vary from 6 in a distance of 2 mm. to 9 or 10 in the same distance. These revolving lines often are not conspicuous and are readily overlooked.

Locality and Position: In the *Holophragma* zone, at the top of the upper or Lilley member of the West Union formation, within the eastern limits of Hillsboro, Ohio.

Platyceras angulatum (Hall).

Plate XVII, Figs. 2 A, B.

For somewhat more than one volution the whorls at the apex of the shell are in contact with each other; then they become free for a distance of at least one volution. There is a slight tendency toward longitudinal ribbing, one rib being peripheral in location, a second being basal, and a third following the inner margin of the last whorl, where the umbilicus would be in a closely coiled shell.

The specimen here figured was found in the Cedarville dolomite in the quarry at Cedarville, Ohio.

Bumastus cf. **ioxus** (Hall).

Plate XVI, Fig. 5.

Illaenus ioxus Hall, 20th Rept. New York State Cab. Nat. Hist., 1868, p. 378, plate 22, figs. 4-11, plate 23, fig. 1.
Illaenus ioxus Weller, Bull. Chicago acad. sci., 1907, no. 4, pt. 2, p. 222, pl. 18, figs. 1-3.
Bumastus ioxus Raymond, Bull. Mus. Comp. Zool. Harvard Coll., vol. 60, no. 1, 1916, p. 20.

Bumastus ioxus was described from the Racine dolomite; it is known to occur both at Joliet, Illinois and at Racine, Wisconsin.

At the *Whitfieldella cylindrica* horizon, nine feet above the base of the Lower or Bisher member of the West Union formation, at the exposures along the hill-front northeast of the Bisher dam bridge, about a mile southeast of Hillsboro, Ohio, a large cranidium of *Bumastus* was found, which evidently is closely similar to that of *Bumastus ioxus*.

In this specimen from the West Union formation the palpebral lobes are relatively smaller and the distance from these lobes to the anterior margin of the cephalon is relatively greater. The facial suture intersects this margin where the latter has not curved as strongly backward as in typical *Bumastus ioxus*. Dorsal furrows faint, broad, and shallow, confined to the area opposite the palpebral lobes. The convexity of the cranidium is only moderate.

Closely similar large cranidia occur in the Osgood limestone, in the vicinity of Osgood and elsewhere in Ripley county, Indiana.

Proetus undulostriatus Hall.

Plate XIX, Figs. 6, 12.

The type of *Proetus undulostriatus* was refigured by Ruedemann in Bulletin 162 of the New York State Museum, in 1912. In this figure (Loc. cit., pl. 9, fig. 2) only the right posterior lobe appears to be differentiated on the glabella. In a second specimen figured in the same bulletin from the same locality and horizon (Loc. cit., pl. 9, fig. 3) three pairs of glabellar furrows are indicated. Of this second specimen Dr. Ruedemann prepared for me an outline drawing (Pl. XIX, Fig. 12) accompanied by the description given below. In view of the great difficulty of distinguishing species of *Proetus* from different Ordovician horizons, these notes by Dr. Ruedemann will prove very useful. Both specimens of *Proetus undulostriatus* were found in the Snake Hill beds in the basal Trenton, at Snake Hill, New York.

"The marginal border and interspace are as represented (in figure 3 on plate 9 of bulletin 162), or rather the interspace is still a little wider than shown in the figure. The glabellar furrows are as faint as represented, only the last lobe stands out a little more distinctly, similarly as in Beecher's figures (Amer. Geol., vol. 16, 1895, p. 173, pl. 9, figs. 5-7). I had still another cephalon of the *Proetus* from the Canajoharie shale, which showed very distinctly set off basal lobes. I have never seen a pygidium of *Proetus undulostriatus*. In the '*Cyphaspis hudsonica*' (Bull. 49, 1901, pl. 4, figs. 8, 9; see also plate XIX, fig 6 in the present paper) the space between the marginal border and the glabella is as represented, the marginal border, however, is broken at the top and the draftsman has represented its width as seen in the broken part. I have no doubt that it is wider than drawn, about as wide as the interspace to the glabella, as shown by the camera outline (here reproduced as Fig. 6 on Plate XIX). There is no depression lining the inner side of the border, nor was it intended to show one, as may be seen from the accompanying profile drawing (Fig. 9 on plate 4, of Bull. 49)."

The specimens of *Proetus* figured by Beecher (Loc. cit., pl. 9, figs. 5-7) from the Utica shales, at Rome, New York, evidently had distinctly defined basal lobes on the glabella and in this respect resemble *Proetus undulostriatus* rather than typical *Proetus parviusculus*. If the segmentation of the pleural ribs on the pygidium is indicated correctly, there are apparently six ribs on each side, occupying all of the space as far back as the end of the axial lobe. Assuming that the ribs are grooved medially, the pygidium still differs from that of typical *Proetus parviusculus*.

Proetus parviusculus, Hall.

Plate XIX. Figs. 11 A, B.

1872. Twenty-fourth Rept. New York State Cab. Nat. Hist., pl. 8, fig. 14.

Proetus parviusculus is cited by Bassler, in his Bibligraphic Index of American Ordovician and Silurian fossils, from the Corryville member of the Maysville formation at Cincinnati, Ohio (Pl. XIX, Figs. 11, A, B.), and a typical specimen from that horizon is figured here.

It closely resembles *Proetus undulostriatus* Hall, from the glabella presents essentially the same outline, narrowing toward the front, with the sides slightly concave at the anterior end of the eyes. Assuming that typical forms of *Proetus undulostriatus* are characterized by the presence of more or less distinct posterior glabellar furrows, *Proetus* *parviusculus* possibly may be distinguished by the entire absence or at least considerable indistinctness of these furrows. In *Proetus parviusculus* the basal lobes may be indistinctly indicated by a slight depression of the glabella there where the furrow limiting these lobes might be expected, but usually this depression is too indistinct to attract attention even on careful search.

The indistinctness of the basal lobes of *Proetus parviusculus*, found in the type specimen of this species, is not confined to specimens of *Proetus* occurring in the Maysville formation, but occurs also in forms found in much lower strata.

A cranidium found in the railroad cut north of Cynthiana, Kentucky, in strata referred to the Cynthiana formation, can not be distinguished from *Proetus parviusculus*.

Another cranidium (Plate XIX, Figs 10, A, B), found in the upper part of the Benson member of the Trenton formation, directly beneath the Brannon member, northwest of Bridgeport, Kentucky, associated with *Strophomena vicina* Foerste, also bears a close resemblance to *Proetus parviusculus*, but the glabella is a little flatter, and there are very faint traces of glabellar furrows, too faint, however, to suggest *Proetus undulostriatus*, if the presence of distinct glabellar furrows be regarded as an essential characteristic of that species.

Apparently those specimens of *Proetus* having distinct basal glabellar lobes are more common in the Ordovician strata of the New York basin, and those with indistinct basal glabellar lobes are more common in the Ordovician areas surrounding Cincinnati, without regard to separation of these strata into Cincinnatian and Trenton formations.

A pygidium of *Proetus* was found half way between Flag run and Emily run, about 4 miles west of Drennan Springs, in Henry county, Kentucky. Here it occurred in that part of the Cynthiana formation to which Ulrich applied the term Gratz. A pygidium was found within five feet above the level of the railroad at the exposure south of DeMossville, on the northern edge of Pendleton county, in strata also referred to the Cynthiana formation. Another pygidium occurred in the Cynthiana formation north of Rogers Gap, Kentucky. The pygidium from the locality west of Drennan Springs possesses the following characteristics:

The axis of the pygidium is prominent, and is crossed by three distinct rings and also by three rings becoming successively much less distinct, leaving at the posterior termination of the axis a space equal in length to that of one or two of the posterior rings. The pleural lobes are marked by three distinct ribs and a fourth, much less distinct rib, leaving an unoccupied space at the posterior end of the axial lobe sufficient for the insertion of a fifth rib, which, however, does not occur. The pleural lobes are convex, excepting toward the margin, where, for a space about as wide as the distance from the termination of the axial lobe from the posterior margin of the pygidium, the curvature is distinctly concave along the entire margin.

Proetus determinatus, Foerste.

Plate XIX, Figs. 14 A-D.

1887. Foerste. Bull. Sci. Lab. Denison Univ., vol. 2, p. 91, pl. 8, figs. 2, 3, 3a.
1913. Savage. Bull. Geol. Surv. Illinois, No. 23, p. 104, pl. 6, figs. 10, 11.

Proetus determinatus as identified by Savage from the gray limestone in the upper part of the Edgewood limestone, near Thebes, Illinois, differs from *Proetus princeps* chiefly in the smaller size of the occipital lobe occurring at each end of the neck ring, and in the presence of distinct furrows along the segments of the pleural lobes of the pygidium.

The lobe at each end of the neck ring evidently originated from the neck ring itself, since only a weak furrow separates it from the latter; this furrow does not actually reach the posterior margin of the neck ring, but reaches the dorsal furrow a slight distance anterior to this posterior margin; it is most distinct where it leaves the neck-furrow. A small granule ornaments the median part of the neck ring. The glabellar furrows are faintly defined or obsolete.

In both *Proetus determinatus* and *Proetus princeps*, the concave flexure limiting the posterior part of the anterior border is separated from the anterior margin of the glabella by only a short distance.

It is probable that the faintly defined or obsolete glabellar furrows are represented, on the under side of the cranidium, by much more strongly defined ridges, and that frequently the presence of the latter may be detected through the partially translucent test.

Proetus princeps, Savage.

Plate XIX, Figs. 13, A, B.

1913. Bull. Geol. Surv. Illinois, no. 23, p. 57, pl. 2, fig. 14.

The cranidium figured by Savage is characterized by the large size of the lobe occurring at each end of the neck ring. These lobes appear to have originated from the neck-ring, having been cut off from the latter by oblique furrows.

The axial lobe of the pygidium is marked by about 10 rings, rather faint near the posterior end of the lobe. The grooves along the ribs of the pleural lobes are either very faint or entirely obsolete. Usually only the three anterior pairs of ribs show traces of these grooves, if any are present.

LOCALITY AND POSITION: Girardeau limestone, near Thebes, Illinois.

Proetus collinodosus, sp. nov.

Plate XVIII, Figs. 7 A, B.

Cranidium 10 mm. in length along the middle; of this length 7 mm. is occupied by the glabella, 1.7 mm. by the anterior border, and 1.3 mm. by the neck-ring. The anterior part of the glabella is in contact with the furrow which outlines the inner margin of the anterior border of the cranidium, and, when viewed directly from above, appears to encroach slightly upon the posterior margin of this border. Posteriorly the glabella has a width of 7 mm., and its general outline is oval-triangular, the sides converging anteriorly at an angle of about 40 degrees. Along its anterior margin the glabella is relatively narrow and opposite the anterior margin of the palpebral lobes the sides of the glabella tend to be slightly concave. The palpebral lobe appears to be 3 mm. in length and, at its widest part, it diverges only 1.5 mm. from the glabellar furrow. The posterior border of the glabella is strongly defined. The neck-ring is comparatively flat for the greater part of its width, and bears a minute tubercle at its middle. Laterally, the ends of this neck-ring curve forward and are nodosely elevated, forming rather conspicuous occipital lobes. These lobes are obliquely elliptical, about one and a half millimeters in maximum width, and are distinctly delimited from the remainder of the neck-ring.

A dissociated free cheek shows the same broad marginal border, and a genal spine similar in size and form to that of other species of this genus.

A dissociated pygidium is 4.5 mm. in length and 8 mm. in width. The posterior part of the axial lobe is about one millimeter distant from the margin of the pygidium. This axial lobe is marked by 6 or 7 fairly distinct rings but there is sufficient room posteriorly to admit of a total of 8 rings. The pleural ribs are indistinctly defined, at least in the only specimen at hand.

Locality and Position: In the *Holophragma* zone, at the top of the upper or Lilley division of the West Union formation, in the Zink or Corporation quarry, in the eastern part of Hillsboro, Ohio.

Remarks: From *Proetus determinatus* Foerste, from the Brassfield formation of Ohio, this species is distinguished readily by the more triangular outline of its glabella, and by the close approach of the anterior part of the glabella to the posterior part of the broad marginal border of the cranidium, only a narrow groove separating the two.

Proetus pachydermatus Barret, from the Helderbergian of New Jersey and Maryland, also has two lateral lobes belonging to the neck ring, but the marginal border of the cranidium is farther removed from the anterior outline of the glabella, and the glabellar furrows are distinct; neither of these features is seen in *Proetus collinodosus*.

Encrinurus cf. **ornatus** Hall and Whitfield.

Plate XVIII, Figs. 2 A-C.

Only a fragment of a cranidium is known. Its length along the middle is estimated at 7 mm., and its width, to the end of the genal angles, but not including the genal spines is estimated at 22 mm. The length of the genal spines is 5 mm. Conspicuous tubercles occur on the glabella, on the more strongly convex part of the cheek which surrounds the eye, and on the marginal rim. On the depressed part of the free cheek, toward the genal angle, the tubercles are inconspicuous. In front of the series of conspicuous tubercles on the free cheeks there is a much less conspicuous series of smaller tubercles. Near the genal angles, one or two tubercles occur also on the posterior border of the free cheek and on the genal spine.

The pygidium is obovate-triangular. Its width is 14 mm., and its length, in its present state of preservation, beginning with the anterior margin of the first annulation, is 17 mm. The posterior end apparently terminated in a short spine extending only slightly beyond that part at present remaining. The length of the axial lobe is 14.5 mm.; anteriorly this lobe is crossed by two annulations, the second of which bears a median tubercle. Posterior to the second annulation the median part of the axial lobe, for about one-fourth of its width, tends to be smooth, the annulations being distinct only along the sides of the lobe. It is rarely possible to count more than 30 annulations, those at the posterior end being indistinguishable, but in remarkably well preserved specimens, in which even the terminal annulations are distinct, as many as 36 may be counted.

In the figured specimen, tubercles occur on the median parts of the axial lobe, at annulations 2, 5, 9, 14, 20, 25, 30?, and ?, the number of the annulations bearing the last two tubercles being uncertain. In a second specimen, tubercles occurred at 2, 5, 9, 14, 19, the location of the remainder being uncertain. In a third specimen, tubercles occurred at 2, 5, 9, 13, 18, 22, 26?, and ?, the location of the last two being uncertain. In a fourth specimen, tubercles occurred at 2, 6, 9, 13, 18, 24, 29, and 33, the axial lobe terminating with the thirty-sixth annulation. That the location of even the first four tubercles may vary is shown by a fifth specimen, in which they occurred at 2, 4, 7, 12, 16, 21, and ?, the location of the last being uncertain. These observations indicate to what an extent the exact location of the tubercles along the median line of the axial lobe varies, and of how little value their location is in the discrimination of species. In general, it may be stated that seven tubercles may be counted frequently along the axial lobe of the species here described, and that an eighth tubercle may be recognized on the better preserved specimens.

There are eight pairs of pleural ribs. The distal parts of these ribs, about 4 or 5 mm. from their ends, curve strongly downward and backward, and appear more or less parallel to the sides of the axial lobe, when viewed from above. In consequence, the posterior ribs have a slightly converging appearance posteriorly, and lie close to the axial lobe. At their distal ends the pleural ribs are lengthened parallel to the margin of the pygidium into a form slightly resembling the foot of a flattened stocking. In consequence, the margin of the pygidium is marked by 7 crenulations; the last pair of ribs does not reach the margin but terminates at a nearly obsolete point a little over a millimeter beyond the end of the axial lobe. When viewed from the lower side of the pygidium it is seen that the margin of the pygidium is abruptly infolded for a distance of about a millimeter beyond the margin of the pygidium as viewed from above. This infolded marginal part is smooth, the pleural ribs terminating at the sharp angle of infolding. The infolded part forms an angle of about 170 or 160 degrees with a horizontal plane passing through this margin. The grooves between the anterior pleural ribs are about half a millimeter in width. At the bottom of each groove there is a slight elevation, extending along its entire length. The tubercles on the pleural ribs are irregularly arranged, the location of the more prominent tubercles apparently being constant. In the accompanying figure, the more prominent tubercles have been accentuated. On the first pleural rib there is a tubercle nearly a third of its length from the axial lobe, the corresponding tubercle on the next rib being situated a little closer. On the third pleural rib the tubercle occurs nearly at mid-length. The tubercles on the fourth and fifth ribs are near the axial lobe, that on the fifth rib being slightly more distant. The tubercle on the sixth rib is a little closer than mid-length, that on the seventh rib is much closer to the axial lobe, and that on the eighth rib is only indistinctly defined near its anterior end.

Locality and Position: In the *Holophragma* zone, at the top of the upper or Lilley division of the West Union formation, in the Zink or Corporation quarry, within the eastern border of Hillsboro, Ohio.

Remarks: Pygidia having the same arrangement of tubercles on the pleural ribs occur also in the Waco division of the Crab Orchard formation, at Irvine, Kentucky. The same arrangement is seen also in typical *Encrinurus ornatus*, described by Hall and Whitfield from the Cedarville dolomite at Eaton and Yellow Springs, Ohio; but the latter appears to be a larger species and the glabella is more convex. The exact arrangement of the tubercles in *Encrinurus reflexus* Raymond (Bull. Mus. Comp. Zool. Harvard, 1916, p. 25, pl. 3, figs. 7, 8), from the Niagaran at Wauwatosa, Wisconsin, is unknown, but the figure of the pygidium bears a close resemblance to known specimens of *Encrinurus ornatus*.

Calymene whittakeri Sp. nov.

Plate XIX, Figs. 9 A, B.

Anterior margin of the cephalon project in front of the glabella in the form of a lip; in the type specimen, for a distance of 3 millimeters. Compared with typical *Calymene senaria* Conrad, from the Trenton of New York, the lip is less elongate and not so nasute; the genal angles are rounded; the surface distinctly granulated, the granules being somewhat coarser than in most species of *Calymene*. The distinctive feature, however, which is regarded as most characteristic of the species, is presented by the pygidium. Here the ribs curve strongly toward the rear so as to become sub-parallel on the posterior half of the pygidium. All of the ribs extend to within a short distance of the margin of the pygidium, and the first four ribs are distinctly furrowed along their entire length. The fifth rib may be furrowed but in that case its inner margin is not limited from the median part of the pygidium posteriorly.

At Fields, about half way between Collingwood and Meaford, on the southern shore of Georgian Bay, in Ontario, the species of *Calymene* here descibed occurs in the Collingwood formation, as exposed on the shore of the bay. It is named in honor of Dr. E. J. Whittaker, of the Geological Survey of Canada, in memory of pleasant days spent together in unravelling the geology of Georgian Bay and Manitoulin island.

Calymene cf. **vogdesi** Foerste.

Plate XVIII, Fig. 6; Plate XIX, Fig. 3.

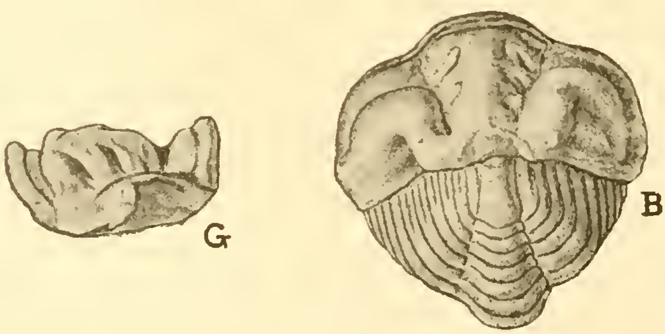
In the *Holophragma* zone, at the top of the Upper or Lilley member of the West Union formation, in the Zink or Corporation quarry, within the eastern limits of Hillsboro, Ohio, a *Calymene* is found which, among described species, most nearly resembles *Calymene vogdesi*, a typical Brassfield species.

In the specimen figured, the anterior rim of the cephalon projects 2.5 mm. beyond the anterior margin of the glabella. The anterior rim forms an angle of from 155 to 145 degrees with the general surface of the base of the cephalon. Compared with typical *Calymene vogdesi* (Plate XIX, Fig. 5), the furrow immediately anterior to the glabella is not as deep; the median part of the glabella, between the lobes, is narrower; the anterior half of the glabella, in front of the second pair of glabellar lobes, is somewhat longer and more quadratic, retaining its width as far as the groove outlining the anterior margin of the glabella. No well preserved pygidia are at hand. In typical *Calymene vogdesi* the pleural ribs extend almost as far as the margin of the pygidium; while in some specimens the ribs are faintly grooved along their entire length, in others the grooving is distinct only near the dorsal furrow and again toward the distal parts of the ribs, or the grooving may be confined practically to the proximal parts of the ribs, near the dorsal furrow.

In the *Calymene* which is so abundant in the Waldron shale in western Tennessee, here identified with *Calymene breviceps* Raymond (Plate XIX, Fig. 2), described from the Waldron shale of Indiana, the rim of the cephalon extends only for a distance of half a millimeter in front of the anterior margin of the glabella, a narrow but distinct groove intervening. Laterally, the anterior rim of the cephalon widens to about one millimeter. In *Calymene celebra* Raymond, (Plate XIX, Fig. 4), from the Niagaran of the Chicago district and from the Springfield limestone of the Eaton quarry, in Ohio, the groove between the anterior margin of the glabella and the anterior rim of the cephalon is deeper, and wider, but the anterior rim is equally narrow. In typical *Calymene niagarensis* Hall, (Plate XIX, Fig. 1), from the Rochester shale of New York, there is also a narrow furrow separating the glabella from the short anterior rim or "lip" of the cephalon.

Platycoryphe Gen. Nov.

In 1898 Pompeckj proposed the genus *Synhomalonotus* (Neues Jahrbuch Min. Geol. Pal. 1, p. 240), founded on *Calymene tristani* Brongniart.



Synhomalonotus tristani Brongniart.

B, enrolled specimen showimg glabella and inverted pygidium.
G, lateral view of glabella showing strongly raised anterior lip.
(Copied from Brongniart, Hist. Crust. Foss. 1822.)

The pygidia of this European species resemble that of *Calymene whittakeri*, figured in this paper (Plate XIX, Fig. 9 B), in the strong backward curvature of the pleural ribs. The median grooves, along the crest of the ribs, do not extend along the entire length of these ribs, but only along their more distal parts. The glabella and the anterior lip are strongly convex from side to side, and although the lateral lobes of the glabella are figured as very oblique, they are at least distinctly defined by deep grooves.

With this genotype, *Synhomalonotus tristani* Pompeckj (Loc. cit., p. 247) erroneously associated an American species, *Calymene christyi* Hall (13th Rep. New York State Cab. Nat. Hist., 1860, p. 118; 15th Rep., ibid., 1862 pl. 10, figs. 2-5), from the Waynesville member of the Richmond, in Ohio, as *Synhomalonotus christyi.* That this association is incorrect is shown by the distinctly different structure of the glabella of the latter.

In *Calymene christyi* Hall (Ottawa Naturalist, 31, 1917, Pl. 6, Fig. 29) the glabella is only moderately convex from side to side; its outline anteriorly tends to be quadratic, and the lateral furrows are relatively shallow. The anterior lip is flat, and does not curve strongly from side to side. The structure of the pygidium of this species is not well known. In the case of *Calymene platycephala* Foerste, (Pl. XIX, Fig. 16 A, B), from the Trenton of Tennessee, both the glabella and the pygidium are known, and the structure of the latter is very characteristic. Its lateral margin is deflected abruptly downward, the deflected part remaining smooth, and the pleural ribs extend only as far as the line of deflection. *Calymene dubia* Savage, (Plate XIX, Figs. 15 A, B), from the Girardeau limestone of Alexander County, Illinois, is congeneric, and another congeneric species, also in the Savage collection, occurs in the Maquoketa, near Yorkville, Illinois. For this group of species, beginning with Calymene christyi, the generic term *Platycoryphe* is proposed.

Since the pygidium of *Calymene platycephala* is better known at present than that of *Calymene christyi*, the former is chosen as the genotype of *Platycorphye.* The cranidia of all the forms here discussed are known.

Platycoryphe dubius, Savage.

Plate XIX, Figs. 15 A, B.

1913. Bull. Geol. Surv. Illinois, No. 23, p, 60, pl. 2, figs. 8, 9.

The only characteristic feature noted in the cranidium was the presence of a pit in each of the dorsal furrows, a short distance anterior to the rather faint anterior pair of glabellar furrows.

The sides of the axial lobe of the pygidium diverge at an angle of 30 degrees. The axial lobe is weakly defined, except along its posterior third, which rises distinctly above the posterior parts of the pygidium. The antero-lateral angles of the pleural lobes are obliquely and abruptly deflected downward at an angle of about 130 degrees with the adjacent part of the pygidium. This deflection is noted also in *Platycoryphe platycephalus* Foerste, from the Trenton of Clifton, Tennessee, with which the Girardeau species was compared by Savage.

In *Platycoryphe platycephalus*, (Plate XIX, Fig. 16 A, B), the lateral margin of the pygidium is abruptly deflected downward, the anterior part of the deflected margin forming an angle of about 130 degrees with the adjacent part of the pygidium. The pleural ribs end abruptly along the line of deflection, the broadly rounded ends of the ribs projecting slightly beyond this line, the marginal part beneath being smooth. In the figured pygidium of *Platycoryphe dubius*, the marginal part of the pygidium, beneath the line of deflection, was not exposed, and hence the line of deflection was regarded, in the original description, as the lateral margin of the pygidium. However, the broadly rounded terminations of the pleural ribs, along this line of deflection, are distinctly visible. Compared with the pygidium of *Platycoryphe dubius*, the axial lobe of *Platycoryphe platycephalus* is more convex, and the furrows separating the pleural ribs are distinct as far as the line of deflection of the lateral margin.

Platycoryphe dubius is characteristic of the Girardeau limestone, in Alexander county, Illinois. Cranidia of *Platycoryphe* occur also in the Maquoketa, near Yorkville, Illinois. These resemble the cranidia of *Platycoryphe christyi*, from the Waynesville member of the Richmond of Ohio; if distinguishing features occur, the later have not been noticed. The pits in the anterior part of the dorsal furrows are small and nearly obsolete.

Ceraurinus cf. **trentonensis** Barton.

Plate XIX, Fig. 7.

Imperfect cranidium. Glabella relatively broader than in *Ceraurinus trentonensis* Barton, from the Trenton on Goat Island, in the northern part of Lake Huron; the lateral outlines of the lateral lobes are less curved; the third pair of glabellar furrows is more oblique, reaching the occipital groove at points less than the width of the third pair of glabellar lobes apart. From the Kimmswick (Prosser) limestone on Sanders Branch, in Ralls county, Missouri.

Pterygometopus confluens, sp. nov.

Plate XIX, Fig. 19.

This species differs from *Pterygometopus callicephalus*, Hall, (Pal. Minnesota Geol. Surv., Vol. III, 1897, p. 731, fig. 51), from the Trenton of New York, chiefly in the confluence of the distal parts of the first and second pairs of lateral lobes of the glabella; the postero-lateral angles of the second pair is rounded. The posterior pair of lobes is small, circular, distinctly defined from the median parts of the glabella, and is located directly beneath the rounded postero-lateral angle of the second pair of lobes. The second pair of lobes also is distinctly defined from the median part of the glabella, and a similar tendency, though much less marked, is shown also by the first pair of lobes. The posterior pair of lobes indents slightly the lateral parts of the neck segment. Between the posterior lobes, the median part of the glabella is transversely rather strongly convex, but between the first and second pairs of lobes the convexity of the median part of the glabella is moderate, and this part of the glabella is at about the same level as the adjacent lateral lobes or is only slightly below the curvature of the latter.

From *Pterygometopus intermedius*, Walcott (Pal. Minnesota Geol. Surv. vol. III, 1897, p. 728, fig. 45), from the Black River formation of Illinois, Wisconsin and Minnesota, it differs chiefly in the confluence of the distal parts of the first and second pairs of lateral lobes of the glabella. The median parts of the glabella, between these lobes, is only slightly depressed, if at all, beneath the curvature of the latter. The first pair of glabellar furrows is not convexly curved toward the front. The margin of the palpebral lobes is more strongly convex in outline, and their posterior margin almost reaches the posterior groove of the fixed cheeks.

With *Pterygometopus eboraceus*, Clarke (Pal. Minnesota Geol. Surv., Vol. III, 1897, p. 728, fig. 49), from the Trenton of New York, it agrees in the confluence of the distal parts of the first and second pairs of lateral lobes of the glabella. The cranidium of the Kentucky specimens here described, however, is relatively much shorter. This is due chiefly to the shorter length of the frontal lobe of the glabella, which is less rhombic in outline, but more transversely elliptical; the first pair of glabellar furrows is more divergent, and the anterior pair of glabellar lobes is less acutely triangular. The posterior margin of the palpebral lobes extends nearer to the posterior groove of the fixed cheeks. Glabella tuberculated; fixed cheeks smooth.

The specimen here figured was obtained from the Tyrone member of the Black River formation, at High Bridge, Kentucky. Cranidia, agreeing in every structural detail with the specimen here figured occur at the same locality, High Bridge, also at two horizons in the Campnelson member of the Stones River formation, 550 and 570 feet above sea level; these cranidia differ from those in the Tyrone member of the Black river formation only in the slightly more prominent tubercles ornamenting the glabella.

From the preceding notes it is evident that *Pterygometopus confluens* belongs to a series of closely related species characterizing the Stones River, Black River, and Trenton formations. Such a series is of little service for purposes of correlation of strata in distant exposures unless the component species are accurately discriminated.

Pterygometopus achates Billings.

Plate XIX, Fig. 8.

"In the specimen figured by Clarke the glabellar furrows were still filled with matrix; on working them out with a needle they gave the figure shown in the enclosed sketch (consisting only of the dotted part of Figure 8 on Plate XIX); the second furrow slopes distinctly backward; the third and fourth are curved, as in the photograph sent by you." (This was a photograph of *Dalmanites carleyi-rogersensis*, as figured from the Rogers Gap member of the Cynthiana formation, in Jour. Cincinnati Soc. Nat. Hist., vol. 21, 1914, pl. 1, fig. 18; see also Fig. 18 A, on Plate XIX, accompanying the present paper). "The neck ring bears a tubercle on the middle of the posterior margin suggesting an incipient spine; this tubercle, however, is not larger than those on the front of the glabella."

An entire individual of this species was figured by Clarke in 1894 (Geol. Minnesota, vol. 3, pt. 2, p. 727, fig. 44), from the Trenton limestone at Trenton Falls, New York. At my request Dr. Rudolf Ruedemann reexamined this specimen and sent the description given above.

Those parts of Figure 8, cited above, which are not dotted, were added to indicate the relative position of the glabellar furrows on the glabella and were not included in Dr. Ruedemann's sketch. These parts may require modification, especially in connection with the neck ring.

Pterygometopus carleyi-rogersensis, Foerste.

Plate XIX, Figs. 18 A, B.

1910. *Dalmanites carleyi-rogersensis,* Foerste, Bull. Sci. Lab. Denison Univ., vol. 16, p. 85.
1914. *Dalmanites achates,* Foerste, Jour. Cincinnati Soc. Nat. Hist., vol. 21, p. 147, pl. 1, fig. 18.

So far no difference is known between the variety *rogersensis,* as found in the Rogers Gap division of the Cynthiana formation, and the typical forms of the species *carleyi,* from the Fairmount division of the Maysville formation, except in size, the Rogers Gap specimens usually being larger. In *Dalmanites carleyi* the first pair of glabellar furrows diverges at an angle of about 140 degrees, the curvature being slightly sigmoid, at first toward the front and then more lateral. The second pair of grooves curves moderately backward and sometimes terminates before actually reaching the dorsal furrows limiting the glabella laterally. The third pair of glabellar furrows curves so as to be directed slightly backward at first and then more or less forward. The corresponding parts of the neck furrow have a similar curvature. The frontal lobe of the glabella is remarkably wide and short, and has a transversely rhomboidal outline. A slightly rhomboidal appearance is characteristic of the anterior outline of the cephalon which tends to be slightly angular immediately in front of the center of the frontal lobe and also in front of the lateral part of the visual surface of the eye. The visual surface (Plate XIX, Fig. 18 B) is composed of 21 or 22 vertical rows of facets, the maximum number of facets in the middle rows being about 11 or 12. In *Dalmanites carleyi* the coarser granules are confined chiefly to the frontal lobe and to the median parts of the glabella; a few occur on the first pair of glabellar lobes, but elsewhere they usually are rare or absent.

In the variety *rogersensis*, these larger granules occur also in moderate numbers on the other glabellar lobes, on the neck ring, and less prominently, even on the fixed cheeks. This may be due chiefly to their larger size. The movable cheeks are smooth macroscopically. The exceedingly minute granules, visible only under a magnifier, covering the entire surface of the cephalon, appear more distinct in some specimens of *carleyi* than in any known specimens of *rogersensis*. In *Dalmanites carleyi* (Plate XIX, Fig. 17), a spinose granule ornaments the middle of the neck ring, close to the posterior margin. The presence of this spinose granule has not been demonstrated in any specimen of the variety *rogersensis*, but this part of the neck ring is defective in all specimens of *rogersensis* found so far.

The type of *Dalmanites carleyi-rogersensis* was obtained north of Rogers Gap, at a point 54.8 miles from Ludlow according to the mile posts along the railroad. Here it occurred in the Rogers Gap division of the Cynthiana formation. A figure of the type specimen under the name of *Dalmanites achates*, was presented in the Journal of the Cincinnati Society of Natural History, cited above, and an enlarged figure of the same specimen is provided here. (Plate XIX, Fig. 18 A).

The posterior extremity of the pygidium of *Dalmanites carleyi* is described as being curved a little upward. This feature is shown also by a specimen of this species in my possession. In a pygidium belonging to the variety *rogersensis*, found north of Rogers Gap, this upward curvature of the posterior extremity also is noted, while in another specimen referred to the same variety, but found east of Hatton, in Shelby county, Kentucky, the curvature of the posterior extremity is distinctly downward. Apparently this can not be recognized as a constant distinguishing characteristic. In the Fairmount specimens of the species *Dalmanites carleyi* the ribs on the pleural lobes of the pygidium are curved more or less backward toward their extremities, especially in case of the more posterior ribs. In the pygidia of the variety *rogersensis*, so far known, these ribs are nearly straight.

Phacops (Portlockia) mancus, sp. nov.

Plate XVIII, Fig. 3.

Anterior part of glabella apparently forming the anterior part of the cephalon; at least no trace of a border is noticed anterior to the glabella except near the lateral margin of the latter; the outline of this anterior part is semicircular. The dorsal furrows limiting the sides of the glabella are distinct, especially where limiting the anterior part of the eye and also posterior to the middle of the palpebral lobe. Four grooves form what here is described as the anterior pair of glabellar furrows; two of these are directed transverse to the length of the cephalon and two are very oblique. The transverse pair is located slightly posterior to the mid-length of the cephalon; this pair is distinct but shallow, about a millimeter and a half in length, and terminates before reaching the dorsal furrow; it has a slightly convex curvature, directed toward the front. A short distance anterior to the lateral extremities of this pair, another pair of grooves is directed obliquely forward; this pair is much more distinct, especially where it enters the dorsal furrows; it also has a slightly convex curvature, the convex side being directed toward the median part of the glabella. The middle pair of glabellar furrows, noted in *Phacops pulchellus*, Foerste, is absent, unless this pair is represented by a slight depression anterior to the inner part of the posterior pair of glabellar furrows. The posterior pair of glabellar furrows is continuous across the median part of the glabella, but is much deeper laterally, especially for a distance slightly more than a millimeter from the dorsal furrows. This furrow is curved backward toward its extremities and that part of the glabella which lies between the transverse anterior glabellar furrows and the lateral parts of the posterior glabellar furrow presents a gently convex, more or less lobate appearance. The occipital groove also is deepest at its lateral extremities; its curvature is sufficiently like that of the posterior glabellar groove to give the intermediate part of the glabella the appearance of a narrow transverse ring. At the lateral extremities of this ring, between the deep parts of the two grooves mentioned, this ring terminates in two small, but distinctly defined circular nodules. A corresponding flexture is noted in the corresponding parts of the neck ring. The groove defining the basal part of the visual surface of the eyes rises along the posterior part of the eyes, defines the inner part of the palpebral lobes, and joins the dorsal furrows anteriorly. Between 18 and 21 vertical rows of facets occur on the visual surface, and the middle rows contain at least 10 facets, but the state of preservation in the specimens at hand is not perfect. The groove traversing the posterior part of the fixed cheeks widens and becomes shallower laterally and merges into the rather indistinct marginal groove of the cephalon. The facial suture extends from the eyes forward and then slightly above the anterior margin of the cephalon to the middle of the latter.

Position and Locality: The specimen figured came from the lower part of the Cedarville dolomite, in the Eastern Mills quarry, southwest of Springfield, Ohio. A second cephalon was obtained within three feet of the base of the Cedarville dolomite, in the quarry at Euphemia, Ohio.

Phacops handwerki, Weller, from the Racine beds near Lemont, Illinois, is described as lacking both the anterior and middle pairs of glabellar furrows, but in other respects the species evidently is closely similar to the Ohio forms here described. The specimens described by Kindle from the Niagaran at Pendleton, Connor's Mill, and Georgetown, Indiana, usually lack all but the continuous posterior glabellar furrow, although sometimes also the anterior and middle glabellar furrows are present. Evidently all of these forms are closely related. Apparently their derivation is from some of the early species of *Pterygometopus*.

A comparison of the Cedarville specimen, described above, with *Phacops stokesii* Milne-Edwards, the type of the subgenus *Portlockia*, indicates that the Cedarville specimen belongs to the same subgenus.

Dalmanites brevigladiolus, sp. nov.

Plate XVIII, Figs. 4 A-E.

Pygidium terminating in a short but relatively very broad spine. In a pygidium whose axial lobe originally must have equalled at least 18 mm., possibly 20 mm., the width of the pygidium at the posterior end of the axial lobe equals 8 or 9 mm.; at 4 mm. from this axial lobe the width of the terminal spine has narrowed to 6 mm.; at 7 mm. it has narrowed to 4 mm.; it terminates at 9 mm. with a very blunt curvature. The axial lobe is rather low and depressed; it is crossed by 15 or 16 transverse rings of which the last three tend to be indistinct; the transverse grooves tend to be less distinctly defined along the median line. Pleural lobes with at least 6 or 7, sometimes possibly 8 ribs, all of which are marked by a median groove. In some specimens the more posterior grooves start off near the posterior margin of the rib and become median at mid-length. For a width of slightly more than a millimeter the lateral margins of the pygidium tend to be smooth, unmarked by the terminations of the pleural ribs. There is a tendency toward extremely low, practically obsolete tuberculation along the axial lobe.

In the only full sized specimen of a cranidium known the glabellar furrows are distinctly defined. The anterior margin of the cranidium has a flat, rounded, median lip-like extension, about the same size as in *Dalmanites platycaudatus*, Weller (Bull. Chicago Acad. Sci., Nat. Hist. Surv., No. 4, pt. 2, 1907, p. 272, pl. 25, figs. 3-5), with which the species evidently is closely related, differing chiefly in the shorter length of the flattened caudal spine.

Position and Locality: In the *Holophragma* zone, at the top of the Lilley member of the West Union formation, in the Zink or Corporation quarry, in the eastern part of Hillsboro, Ohio.

Dalmanites cf. **verrucosus** Hall.

Plate XVIII, Fig. 5.

In the Cedarville dolomite at Cedarville, Ohio, a cephalon was found which bears a close resemblance to *Dalmanites verrucosus* Hall, from the Waldron shale of Indiana. The Cedarville specimen is a cast of the interior of the test.

There is no evidence of tuberculation. The broad prolongation of the median part of the anterior border of the cephalon is a little narrower than in the Waldron species. The anterior pair of glabellar lobes is broad, so that the posterior margin of the frontal lobe is not sharply defined. Neither the second nor the third pairs of glabellar furrows reach the dorsal grooves, differing apparently in this respect from the Waldron species. Some of the associated pygidia are strongly tuberculated, but there is a possibility of the cephalon here figured being a new species.

Acrolichas Gen. nov.

Cranidia as in the European genus Amphilichas. Pygidia differing as follows: Three pairs of ribs, all with free tips; axial lobe narrowing posteriorly to an acute point which reaches the notch between the free tips of the posterior pair of ribs. Genotype: *Lichas cucullus* Meek and Worthen, from the Kimmswick limestone of Illinois and Missouri. (Geol. Surv. Illinois, 3, 1868, p. 299, Pl. I, Figs. 6, a, b, c; cranidium only.)

EXPLANATION OF PLATES.

PLATE XVI.

Fig. 1. *Schuchertella prosseri* Foerste. A, brachial valve of a very convex elongate form; B, pedicel valve of a less elongate form; C, profile of specimen A; D, profile of specimen B, joined with that of a brachial valve of ordinary convexity; E, cast of interior of pedicel valve, showing cast of muscular area. Bisher member, from the hill-front northwest of Bisher dam bridge, southeast of Hillsboro, Ohio.

Fig. 2. *Stropheodonta* (*Brachyprion*) *plana* Foerste. A, cast of interior of pedicel valve; B, profile of same. Bisher member; on James Sanderson farm, north of Danville, Ohio.

Fig. 3. *Rhynchotreta americana* Hall. A, brachial valve; B, lateral view. From the Bisher member, in the southeastern part of Hillsboro, Ohio.

Fig. 4. *Atrypa reticularis elongata* Foerste. A, pedicel valve; B, brachial side; C, lateral view. From Bisher member, in southeastern part of Hillsboro, Ohio.

Fig. 5. *Bumastus* cf. *ioxus* (Hall). Cranidium, from Bisher member, in southeastern part of Hillsboro, Ohio.

Fig. 6. *Whitfieldella cylindrica* (Hall). A, brachial side; B, lateral view. From Bisher member, on James Sanderson farm, north of Danville, Ohio.

Fig. 7. *Spirifer niagarensis* (Conrad). A, pedicel valve; B, brachial valve. From the Bisher member, on the James Sanderson farm, north of Hillsboro, Ohio.

Plate XVII.

Fig. 1. *Atrypa reticularis hillsboroensis* Foerste. A, pedicel valve; B, brachial valve; C, anterior view, with pedicel valve on top; D, brachial valve from another specimen. From Holophragma zone in Lilley member, in Zink quarry, in eastern part of Hillsboro, Ohio.

Fig. 2. *Platyceras angulatum* (Hall). A, B, two views of the same specimen; at the tip of the complete specimen the volutions are in contact, but in the cast of the interior here figured this apical part is not preserved. The apical part separated from the cast and remained on another fragment of the containing rock. From the Cedarville dolomite, at Cedarville, Ohio.

Fig. 3. *Rhynchotreta americana* Hall. Brachial side. From the upper part of the West Union formation, south of Carrs station, in Lewis county, Kentucky.

Fig. 4. *Camarotoechia indianensis* (Hall). A, lateral view; B, pedicel valve; C, brachial valve. From the Holophragma zone in the Lilley member, at Zink quarry, in eastern Hillsboro, Ohio.

Fig. 5. *Camarotoechia* cf. *neglecta* (Hall). A, lateral view; B, pedicel valve; C, brachial valve. From Holophragma zone, in Zink quarry, in the eastern part of Hillsboro, Ohio.

Fig. 6. *Dinobolus conradi* (Hall). Pedicel valve, cast of interior. From Cedarville dolomite, at Mills quarry, southwest of Springfield, Ohio.

Fig. 7. *Trochonema fatuum* (Hall). A, natural size; B, enlarged. From the Holophragma zone, at Zink quarry, in eastern Hillsboro, Ohio.

Fig. 8. *Poleumita prosseri* Foerste. A, lateral view; B, apical view; C, umbilical side. From Holophragma zone, in Zink quarry, in eastern Hillsboro, Ohio.

Fig. 9. *Poleumita paveyi* Foerste. A, lateral view of partially deformed specimen; B, apical view, oblique; C, umbilical view, partially distorted. From Holophragma zone, in Zink quarry, in eastern part of Hillsboro, Ohio.

Fig. 10. *Diaphorostoma hillsboroensis* Foerste. A, lateral view, showing aperture; B, lateral view, from opposite side, of a second specimen; C, basal view, showing aperture; D, apical view. From Holophragma zone, in Zink quarry, in eastern part of Hillsboro, Ohio.

Plate XVIII.

Fig. 1. *Stropheodonta (Brachyprion) newsomensis* Foerste. A, interior of pedicel valve; B, C, interiors of brachial valves. From Holophragma zone in Lilley member, in Zink quarry, in eastern Hillsboro, Ohio.

Fig. 2. *Encrinurus* cf. *ornatus* Hall and Whitfield. A, pygidium; B, obliquely lateral view of same; C, part of cephalon. From Holophragma zone at Zink quarry, in eastern Hillsboro, Ohio.

Fig. 3. *Phacops* (Portlockia) *mancus* Foerste. Cephalon. From Cedarville dolomite in eastern Mills quarry, southwest of Springfield, Ohio.

Fig. 4. *Dalmanites brevigladiolus* Foerste. A, B, C, fragments of pygidia; D, E, fragments of cranidia. From Holophragma zone, at Zink quarry, in eastern part of Hillsboro, Ohio.

Fig. 5. *Dalmanites* cf. *verrucosus* Hall. Cast of lower side of cephalon. From Cedarville dolomite, at Cedarville, Ohio.

Fig. 6. *Calymene* cf. *vogdesi* Foerste. Cranidium; see also Fig. 3 on Plate XIX. From Holophragma zone, at Zink quarry, in eastern part of Hillsboro, Ohio.

Fig. 7. *Proetus collinodosus* Foerste. A, cranidium; B, pygidium. From Holophragma zone, at Zink quarry, in eastern part of Hillsboro, Ohio.

PLATE XIX.

Fig. 1. *Calymene niagarensis* Hall. Profile of glabella and narrow anterior lip. Rochester shale; Lockport, New York.

Fig. 2. *Calymene breviceps* Raymond. Profile of glabella and narrow anterior lip; five lobes can be distinguished on each side of the glabella here figured. Waldron shale; Newsom, Tennessee.

Fig. 3. *Calymene* cf. *vogdesi* Foerste. Profile of glabella and broad flat anterior lip. In Holophragma zone in Lilley formation. Hillsboro, Ohio.

Fig. 4. *Calymene celebra* Raymond. Lip separated from anterior part of glabella by deep groove. Cedarville dolomite; Cedarville, Ohio.

Fig. 5. *Calymene vogdesi* Foerste. Broad lip separated from anterior part of glabella by a wide groove. Top of Brassfield formation, at Centerville, Ohio. Type specimen.

Fig. 6. *Proetus undulostriatus* (Hall). Sketch of type of *Cyphaspis hudsonica* Rudemann (Bull. New York State Mus., 49, 1901, p. 64, pl. 4, fig. 8), made by Dr. Ruedemann to indicate the present condition of the specimen. Snake Hill division of Trenton, on Green Island, near Albany, New York.

Fig. 7. *Ceraurinus* cf. *trentonensis* Barton. Part of cranidium. Kimmswick limestone, Sanders Branch, Ralls county, Missouri.

Fig. 8. *Pterygometopus achates* (Billings). Glabellar portion of the specimen figured by Clarke (Geol. Minnesota, 3, pt. 2, 1894, p. 727, fig. 44) as *Dalmanites achates* Billings, from the Trenton at Trenton Falls, New York. The glabellar furrows on the left side of this specimen were cleaned out and the enlarged drawing was prepared by Dr. Ruedemann.

Fig. 9. *Calymene whittakeri* Foerste. A, cranidium; b, same enrolled specimen, but placed so as to expose the pygidium, inverted. From the Collingwood formation, at Fields, half way between Collingwood and Meaford, on south side of Georgian Bay.

Fig. 10. *Proetus* cf. *undulostriatus* (Hall). A, cranidium; B, lateral profile. From the Strophomena vicina horizon, in the Trenton, northwest of Bridgeport, Kentucky.

Fig. 11. *Proetus parviusculus* Hall. A, cephalon; B, lateral profile. From Corryville member of Maysville formation, at Cincinnati, Ohio.

Fig. 12. *Proetus undulostriatus* (Hall). Sketch of original specimen identified as *Proetus undulostriatus* by Dr. Ruedemann (Bull. New York State Mus., 162, 1912, p. 117, fig. 3) from the Snake Hill member of the Trenton, at Snake Hill, New York.

Fig. 13. *Proetus princeps* Savage. A, an attempted restoration of the cranidium figured by Savage. B, pygidium referred to this species by Savage, in his collection. From the Girardeau limestone, near Thebes, Illinois.

Fig. 14. *Proetus determinatus* Foerste. A, B, cranidia; B, from the Savage collection, but not a figured specimen. C, cephalon, showing traces of glabellar furrows, but these traces are much accentuated in the figure. D, pygidium. From the Edgewood limestone, at Thebes, Illinois.

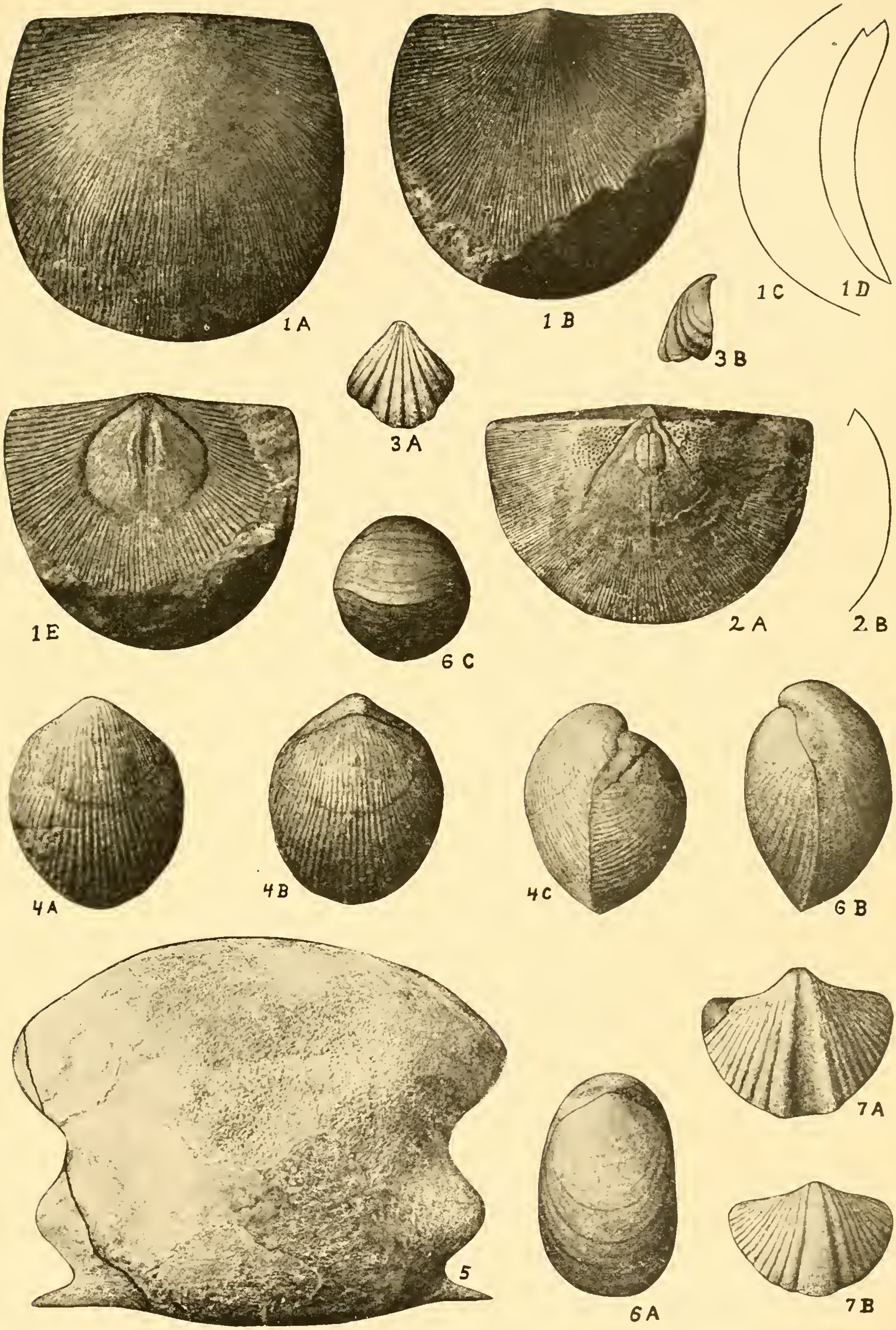
Fig. 15. *Platycoryphe dubia* (Savage). A, attempted restoration of cranidium (type) figured by Savage. B, pygidium (type) figured by Savage. (*Calymene dubia* Savage, Bull. Geol. Surv. Illinois, 23, 1913, p. 60, pl. 2, figs. 8, 9). From the Girardeau limestone, in Alexander county, Illinois.

Fig. 16. *Platycoryphe platycephala* Foerste. A, pygidium (type) seen from above; B, obliquely lateral view of same. (= *Calymene platycephala*). From the Saltillo member of the Trenton, at Clifton, Tennessee.

Fig. 17. *Pterygometopus carleyi* (Meek). Cephalon, from Fairmount member of Maysville formation, at Cincinnati, Ohio.

Fig. 18. *Pterygometopus rogersensis* Foerste. A, Cast of under side of cephalon slightly restored; B, free cheek, with occular surface attached. A, *Dalmanites achates*, five miles north of Rogers Gap, Kentucky, along the railroad, (Jour. Cincinnati Soc. Nat. Hist. 21, 1914, pl. 1, fig. 18), from Rogers Gap member of Cynthiana formation. B, from bridge 54, west of Million tunnel.

Fig. 19. *Pterygometopus confluens* Foerste. Cranidium. From Tyrone member of Black River formation, at High Bridge, Kentucky.



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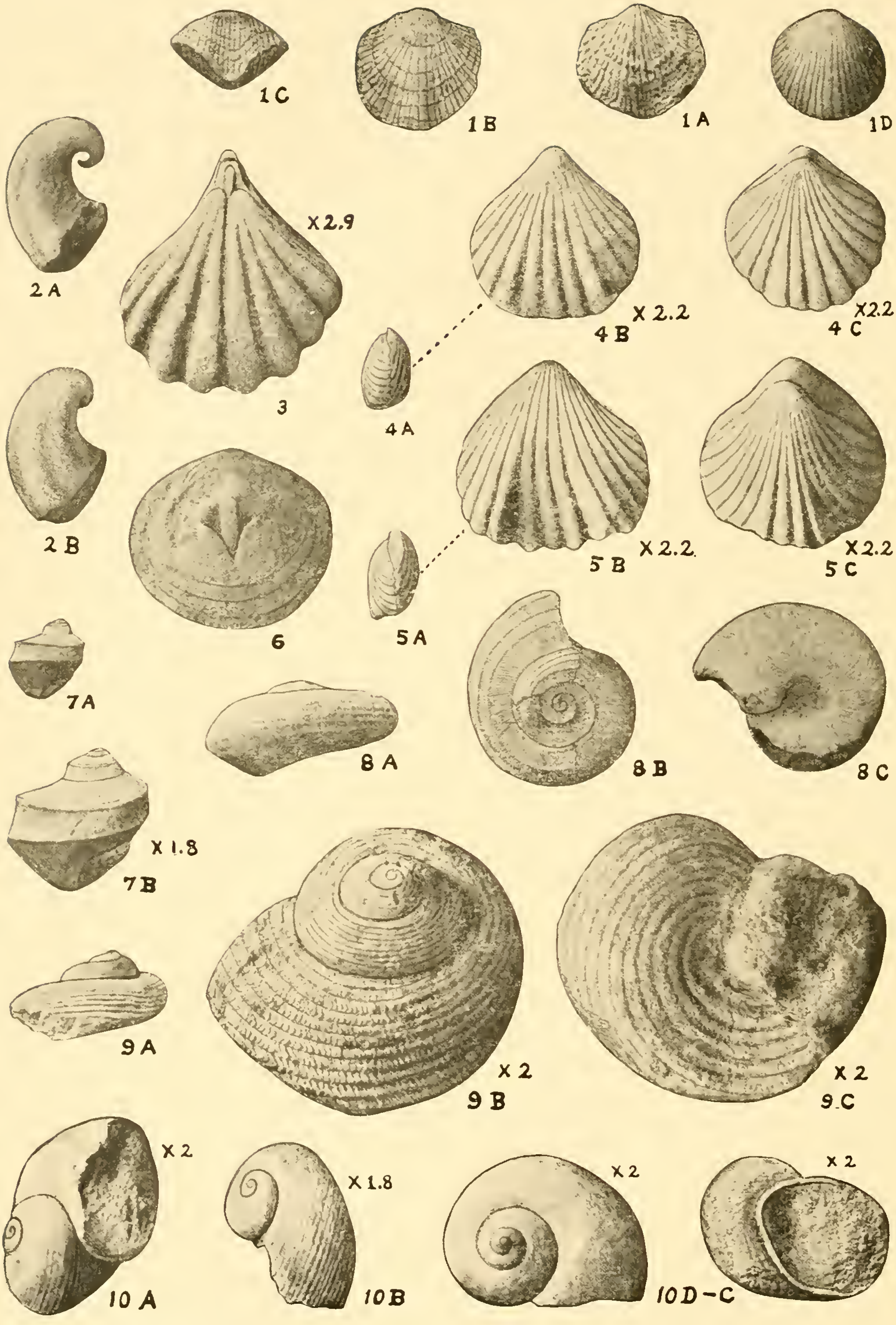

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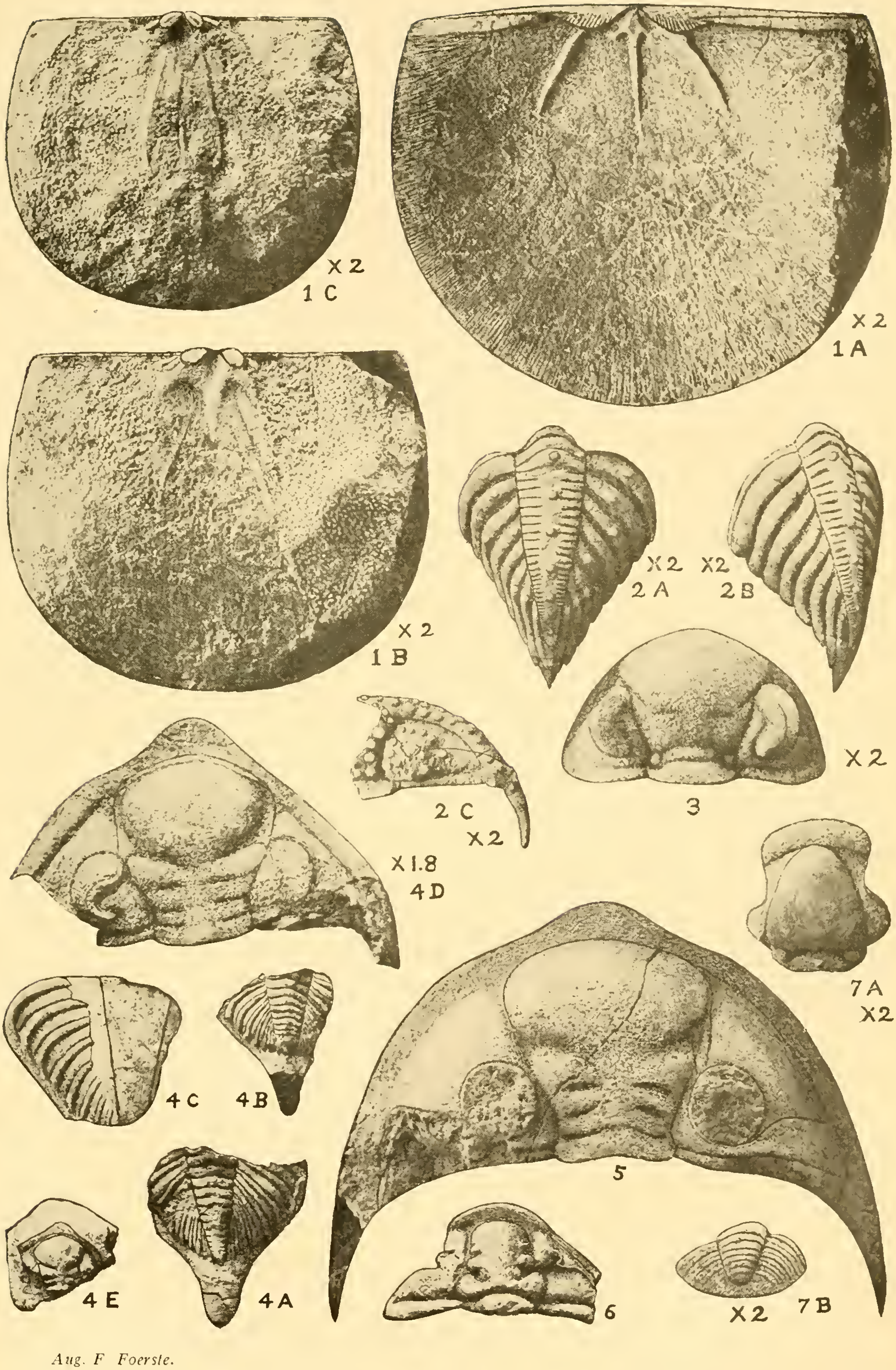

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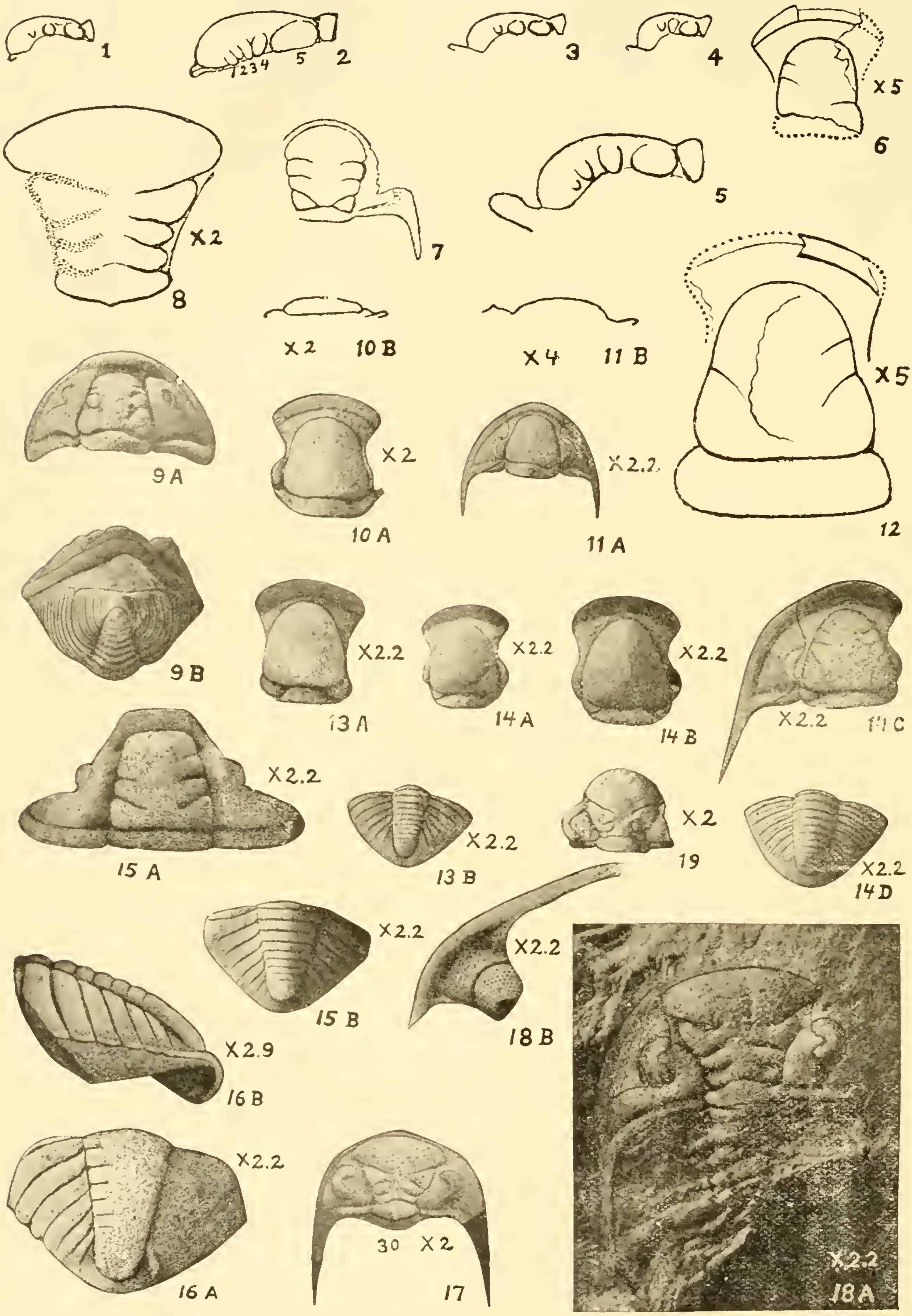

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THE NATURE OF THE DIECIOUS CONDITION IN MORUS ALBA AND SALIX AMYGDALOIDES.*

JOHN H. SCHAFFNER.

In a recent article on "The Expression of Sexual Dimorphism in Heterosporous Sporophytes"† the writer referred to the nature of the sexual development in diecious plants, giving a number of examples of intermediate types of flowers and inflorescences as observed in various diecious species. It was maintained that sexuality as expressed in the sporophyte is a state which in most higher plants arises in the vegetative tissues. It has seemed to the writer that many geneticists have attempted to establish an arbitrary formula to explain sexual phenomena which cannot be applied to the great preponderance of known facts in regard to sex in plants and animals. The simplest sort of observations on a large number of species, especially when they are studied in phyletic series, will plainly indicate that sexuality is quantitative. The state of maleness or femaleness not only varies in degree in different individuals of the same species but also among many independent groups of species.

Morus alba L.

To discover something of the nature of dieciousness in a typical plant by mere observation, the writer chose for one study some trees of Morus alba L., the white mulberry, growing on his old home farm in Clay County, Kansas, where about forty years ago a small grove of this species was planted from nursery stock. These plants soon began to give rise to seedlings scattered along the ravines of the farm and there are now a considerable number of such trees, from ten to thirty years old, available for the study. The trees are all wild seedlings and have had no artificial treatment except that occasionally a limb has been torn down by the wind or removed by the ax and the tops of some have died off because of the dry climatic conditions of the prairie. It is important in such a study to know that the plants have not been grafted in any way.

Altogether 66 trees were studied while they were in full bloom in the months of May and June. The trees graded from apparently pure carpellate to pure staminate. Of course, the

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* Papers from the Department of Botany, The Ohio State University, No. 107.
† Ohio Journal of Science. 18 : 101–125.

trees listed as pure may not have been absolutely monosporangiate, since catkins or flowers of the opposite nature may have been present and overlooked. When one has to go over a tree of considerable size, one may miss even what one is looking for with the greatest care, but the presumption is that they were really pure plants. But even if not, the general nature of the tree was typically carpellate or staminate and this is the important point. At the blooming period there is, besides the striking difference between the catkins, a marked difference in appearance between the staminate and carpellate trees. The staminate trees usually have few leaves at the time of blooming while the carpellate trees have abundant leaves and a more vigorous appearance in general.

Of the 66 trees examined, 28 were apparently pure carpellate individuals, 24 were apparently pure staminate, and 14 were intermediates—or 42+% carpellate, 36+% staminate, and 21+% intermediate. This is not far from 40% carpellate, 20% intermediate, and 40% staminate, which probably approximates the general condition. In other words the pure carpellate and pure staminate individuals are about equal to each other and the intermediate individuals number about one-half of either of the pure types, or about one out of every five trees studied.

The intermediate trees were of varying degrees of carpellateness or staminateness. It is simply stating a matter of fact then to say that in these individuals sexuality expressed as maleness or femaleness is entirely quantitative and may be developed in any degree.

Of the 14 intermediates, 5 were observed to be more carpellate or prevailingly so, 5 about half and half carpellate and staminate, 3 were prevailingly staminate, and 1 was a staminate tree with 3 of its main branches purely staminate but the fourth main branch was decidedly carpellate although still producing many staminate catkins. This tree is described in greater detail below.

The following descriptions show the characteristics of each of the 14 intermediate trees:

1. Carpellate tree occasionally having a carpellate catkin with a few stamens. The tree has only a very slight male tendency. No complete staminate catkin was discovered but some catkins were about half and half.

2. Carpellate tree with a few carpellate catkins having some stamens. This tree was about like the preceding in sexual expression.
3. Carpellate tree with here and there a carpellate catkin having a few staminate flowers.
4. Carpellate tree with a considerable number of staminate catkins, scattered here and there. In some cases the staminate catkins were in the same cluster as the carpellate. Also some carpellate catkins had a few stamens. This tree has female expression with a strong male tendency.
5. Carpellate tree with many staminate catkins and many mixed. There is a very strong tendency to male expression.
6. A tree with about half carpellate and half staminate catkins with some mixed. The staminate are apparently slightly more numerous.
7. Tree with about an equal number of staminate and carpellate catkins, with very many catkins having both stamens and carpels. A decidedly bisporangiate individual.
8. Tree with about an equal number of staminate and carpellate catkins and also with some mixed catkins.
9. A tree of about the same nature as number 8.
10. An individual having about equal numbers of staminate and carpellate flowers. Most of the catkins have both stamens and carpels in varying degrees.
11. Tree mostly staminate, with here and there a carpellate catkin or partially carpellate catkin on small branches in various parts of the tree.
12. Tree prevailingly staminate, with here and there a carpellate catkin; also with catkins having both kinds of flowers. Male sex is characteristic, with a considerable female tendency.
13. A tree prevailingly staminate, but with careful search showed a very few carpellate catkins. Male sex is expressed with a slight female tendency.
14. A wild seedling tree about 20 years old with a main central branch and three large side branches. One large branch had been cut off. This tree was a staminate tree covered with staminate catkins. Of the three large side branches two showed nothing but pure staminate catkins. The third had reversed the sexual state to a remarkable degree and was decidedly carpellate in all of its parts. It produced over 1000 fruits which came to maturity. However, the reversal was not complete for this branch produced some pure staminate catkins and also some catkins with both staminate and carpellate flowers. The main or central branch was also purely staminate except that near the top of the tree there was a small twig which produced four carpellate catkins which developed into fruits. In this twig evidently the same reversal of the sexual state had taken place as in the large branch farther down. The large reversed branch was 4 inches in diameter at the base and 12 feet long.

Omitting the tree with the reversed branches, the remaining 65 individuals may be arranged to indicate roughly the degree of femaleness or maleness as follows:

Pure female expression.	Female with very slight male expression.	Female with considerable male expression.	Female with strong male expression.	Female and male nearly equally expressed.	Male with slight female expression.	Male with very slight female expression.	Pure male expression.
28	3	1	1	5	2	1	24

In the case of number 14, we have an example of the reversal of the sex condition in the vegetative tissues of a bud, which is more fundamental than the dimorphic hereditary expression which appears when two catkins of opposite nature are produced side by side, although the cause may be the same in either case. The main trunk with the male condition established, or at least with a strong tendency toward producing staminate catkins, suddenly gives off a bud with the opposite tendency which continues in scores of secondary buds and branches. The change from staminate to carpellate condition was, however, not complete. The reversal in sexual nature was not able to repress the male condition entirely, and so there are here and there catkins which have the staminate nature—an expression of maleness in the ultimate shoot, although the prevailing tendency of the entire branch is female. The seeds of the fruit are perfectly viable and little trees are being grown from it at the present time.

There could be no more striking example of the reversal of sex in a vegetative tissue and the prevailingly consistent behavior of its parent tissue than is shown in this tree. The process, however, can be no different, fundamentally, than what goes on in the vegetative tissues of monecious and bisporangiate flowers generally; but the case is interesting because of its bearing on diecism, and because of its persistence in the given branch. There is something in this derived vegetative tissue, derived apparently from male tissue, which compels female expression generally but permits a reversal to the male condition again occasionally. This "something" has nothing to do directly with the fundamental factors of male and female organs or gametes, for all such factors are present in these cells; nor is there any relation to a reduction division, nor to any other possible shifting of hereditary sexual units. All of the sexual hereditary factors are present and functioning at certain points in cells derived by vegetative division from a previous, common, mother cell.

This interesting example shows that a sex reversal can and sometimes does take place in an old tissue whose cells are removed by thousands of vegetative divisions from the original zygote. It assures us that sex control is only a matter of finding out how to change the prevailing physiological state of the tissues in some way corresponding to the change of state which actually takes place in living bodies without any apparent external cause. It is reasonable to believe that a change in sexual state could be accomplished much more readily in the zygote, or the cells coming immediately from it, than in an older tissue where the particular condition presumably has been intensified by its longer continuance, whether the state is due to accumulated chemical bodies or to some other cause.

Salix amygdaloides Anders.

During the same period, the writer studied the diecious nature of the peachleaf willow, Salix amygaloides Anders., on the same farm. There is a grove of about 100 trees which has developed in a ravine that was formerly pure prairie, within the memory of the writer. One cannot be certain of the exact number of individuals, as this species sprouts abundantly from the base and forms clumps of shoots or trees which have a common vegetative origin. In older specimens it is not possible to tell absolutely whether a given clump represents a single individual or two or more.

Out of the 100 trees 9 individuals were found intermediate while the rest seemed to be normal staminate or carpellate. However, since the study was begun rather late in the blooming period there may have been some apparently carpellate individuals that had previously produced staminate catkins. The study was, therefore, confined to the nine intermediate individuals discovered. From a superficial knowledge of this species of willow, the writer believes that intermediates are quite rare and not commonly produced as in the white mulberry.

All of the nine intermediate individuals seemed to be primarily staminate, ranging from a few to many carpellate catkins or bisporangiate catkins on a plant. One individual, however, had a considerable proportion of carpellate or fruiting catkins and produced considerable seed. Still it was prevailingly staminate.

In most cases, the carpellate catkins were staminate below and became carpellate at the outer end, usually at or somewhat above the middle. The axis of such catkins changed from the staminate state to the carpellate state. The staminate flowers below were normal for the species and the carpellate flowers near the tip appeared normal and finally discharged mature seed in the usual manner. But on the transition zone, between the staminate and carpellate parts, the axis seemed to be neutral in regard to sex and here bisporangiate flowers were frequently present, the same as is commonly observed in normal monecious inflorescences where one part is staminate and the other carpellate. In the neutral zone abnormal flowers were very frequent. In some cases structures developed which were partly staminate and partly carpellate. Or a stamen would have some carpellate characteristics or a gynecium take on some of the peculiarities of a stamen.

The development of organs in such transition zones is very interesting, since it indicates that the differential sexual state is not sufficiently strong in one direction or the other to make the factors which control the expression of one or the other set of organs entirely latent or entirely active. In consequence of the lack of such control, there is an attempt, so to speak, to develop both male and female characters in an organ which phylogenetically, and normally in its ontogeny, is purely male or purely female in expression. The reversal of the sexual state in the middle of the catkins is not abrupt but there is a gradual change in the tissues from one condition to the other. It is a quantitative change; and thus it necessarily follows that the characters developed through the activity of the hereditary factors are also quantitative in respect to maleness and femaleness. In these catkins the reversal of sex is from male to female as in the inflorescence of Zizania aquatica L. In other plants like Tripsacum dactyloides L. it is just the opposite.

The conclusion from the evidence presented above seems to be inevitable, that sex expressed as maleness or femaleness is not an irreversible, Mendelian, hereditary character, dependent on the presence of a single hereditary factor or group of factors, but is a physiological state or condition which influences the activity and latency of the factors that control the development of sexual gametes or organs, or other sexual peculiarities possessed by the organism.

An examination of the life cycle of one of the higher plants, like Selaginella kraussiana (Kunze), shows that sexuality as expressed in the male and female gametophytes, or as slightly indicated in the microsporophylls and megasporophylls of the sporophyte, is not Mendelian and cannot have any relation whatever, primarily, to Mendelian factors, or Mendelian combinations and segregations; for the simple reason that the beginning of sexual differentiation is initiated in the tissues of the mature sporophyte. Furthermore, when the reduction division occurs in which the synaptic chrosomes are segregated and with them the possible Mendelian factors the four megaspores or the four microspores resulting are not half of one sex tendency and half of the other, but all of the four spores resulting from a reduction division are of the same sexual state and all four give rise to females or all four to males, depending on which sexual state was established in the tissue from which the sporocyte originated. Again, after the gametophytes have developed and matured their gametes, the resulting zygote is not determined as male or female, or more properly speaking as microsporangiate or megasporangiate, but the resulting sporophyte is neutral until it begins to form its strobili when both male and female expression originate side by side in its vegetative tissues as stated above. It is simply impossible to think of a Mendelian formula for the sexual expression of such plants when the ontogenetic processes do not permit combinations and segregations of sex-determining factors to take place in the chromosomes. In consequence of the above facts it comes about that in this species of Selaginella the proportion between the sexes of the gametophyte generation is about 1 female to 5,000 males instead of about 1 to 1, as would follow if sexuality were controlled by factors segregated in the reduction division.

This conclusion has been evident to the writer ever since he began to plot the life cycles of plants as an aid to teaching in general botany. In the first edition of his "Laboratory Outlines for the Elementary Study of Plant Structures and Functions from the Standpoint of Evolution"* the following statement is made: "Male or female sex is not an inherited

* Journal of Applied Microscopy and Laboratory Methods, 5 : 2056. 1902.

quality, but depends on the environment present during the germination of the spore and the development of the embryo, and it can be directly controlled in many cases by artificial means." A statement of similar import has been included in the several editions of the "Outlines" published independently from time to time. In the fourth edition entitled "Laboratory Outlines for General Botany," 1915, the more carefully worded statement appears on page 23 as follows: "Maleness or femaleness is not an hereditary character or factor, but a condition, and often depends on the environment present during the germination of the spore or the development of the embryo." In the meantime, after the knowledge of mutations and the Medelian discoveries had become generally known, the problem of sex has received renewed attention from numerous investigators many of whom attempted to develop a general Mendelian formula for sex, assuming the one sex to be homozygous and the other heterozygous. There have, however, been many whose experimental work has been in substantial agreement with the undeniable conditions as presented by the Selaginella type of plants. The remarkable work of O. Riddle on pigeons has opened up a new line of attack on the problem connected with the higher animals which may well be carefully considered by experimental botanists.

In conclusion the writer will present a number of paragraphs from an article published in 1910, on "The Nature and Development of Sex in Plants,"† in which the problem is discussed from various angles. Among other conclusions expressed the following seem appropriate here:

"Sexuality expressed as maleness or femaleness, whether in gametes, sexual organs, or individuals, is a condition and not a character" (factor).

"Sex may be determined sometime before reduction and thus independently of any process going on during either a vegetative or reduction karyokinesis; it may be determined during the reduction division; it may be determined during the fertilization stage; or finally, it may be determined after vegetative growth has begun."

"In some cases, when the sex is once determined it cannot be changed in the vegetative body nor any vegetative spore or propagative bud; in other cases, it may be changed in the vegetative body after being developed as male or female."

† Proc. Ohio Acad. of Sci. 5 : 321–350.

ON SOME NORTH AMERICAN TINGIDÆ (HEMIP.)*

Carl J. Drake.

During the past three years the writer has been collecting data and preparing to monograph the American species of Tingidæ occurring north of Mexico. Through the kindness of numerous workers many specimens have been studied from various parts of the United States. As this paper will not be completed for several months, it seems desirable to publish the following notes and descriptions of new species.

Corythucha montivaga, new species.

Hood moderately large, slightly constricted near the middle, the height equal to about three-fifths of its length, slightly longer than the median carina and a little more than twice as high. Median carina with large, long (mostly rectangular) areolæ, nearly straight in the female but slightly arched in the male; lateral carinæ moderately long, arched near the middle and the areolæ becoming smaller towards both the anterior and posterior ends. Paranota with the reticulations slightly smaller than those of the globose portion of the hood, the anterior margins beset with a few spines. Lateral margins of paranota and elytra unarmed. Elytra broad, the lateral margins narrowed and rounded posteriorly; costal area triseriate. Tumid elevations narrow, moderately high and pointed. The elytra (taken together) are subequal in width (near base) and length, the entire insect being broadly ovate in outline.

General color yellowish brown with fuscous markings. Greater portion of hood, part of paranota and spot on median carina fuscous. Elytra with a band across the base and apex fuscous; both bands contain partly hyaline areolæ and the apical band extends along the apex of the elytra. Sutural area with fuscous markings. Body beneath black.

Length, 3.4 mm.; width, 2.2 mm.

Type (male) and allotype (female), collected on Bear Pw. Mt., Montana, September 3 (from the late McElfresh collection). Akin to *C. padi* Drake, but readiy separated from it by the slightly elevated hood, the shape of the median and lateral carinæ and the lateral margins of the elytra.

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*Contribution from the Department of Forest Entomology, the New York State College of Forestry, Syracuse, N. Y.

Corythucha ciliata Say.

In Missouri Hollinger took several specimens, including both nymphs and adults, upon ash (*Fraxinus* sp.), hickory (*Carya ovata*) and paper mulberry (*Broussonetia papyrifera*). The primary food plant of this insect is sycamore, *Platanus occidentalis*.

Corythucha gossypii Fabricius.

Eggs, nymphs and adults were found upon castor bean in Florida during the summer of 1918. The reported food plants are cotton and *Ichtyonethia piscipula*. Specimens from Florida, West Indies and Mexico show much variations in color.

Corythucha celtidis Osborn and Drake.

Specimens have been examined from Ohio, Kentucky, Tennessee and South Carolina. The specimens from Tennessee are considerably darker in color and slightly larger than types or other specimens from central Ohio. The Ohio and South Carolina specimens are from hackberry.

Corythucha obliqua Osborn and Drake.

It is impossible to separate *Corythucha maculata* Van Duzee (according to *paratype* kindly sent to me by the author) from this species and *maculata* should be placed as a synonym of *obliqua*. In Prof. H. G. Barber's collection Gibson determined an almost typical form of *obliqua* from California (called *C. fuscigera* by Van Duzee and later described by him as *maculata*) *contaminata*. In my collection Gibson identified teneral or off-color forms of *obliqua* from Moscow, Idaho, as *contaminata*. *Obliqua* is somewhat variable in size and color and it is not uncommon to find both color bands of the elytra more or less evanescent. The hood varies slightly in size, but not near as much as it does in a few other species. *Contaminata* may prove to be a variation or variety of *obliqua*, but at present it seems best to consider *contaminata* a distinct species until type has been examined. *Obliqua* is one of the most common tingids in the western part of United States and feeds on *Cœnothus spp.*

Gibson quite erroneously states (Trans. Am. Ent. Soc., Vol. XLIV, p. 82) that Osborn and Drake place *contaminata* synonymous with *distincta*. In the late McElfresh collection there were many specimens of typical *Corythucha distincta* O & D under the name "*Corythuca contaminata* Uhler MS." In fact some of these specimens bear the same locality and number label ("Colo. 626") as type and were undoubtedly collected with the type. In the late Heidemann collection, now at Cornell University, there is a long series of specimens of *Corythucha pallida* O & D under the manuscript name *Corythucha contaminata* Uhl.; this label is written in Uhler's own hand writing. Furthermore, I have seen two or three other species bearing this same manuscript name. It seems entirely inept to put the "manuscript" or "cabinet" names of insects in literature, especially when there are several species under the same name or several names refer to the same species and when these names have never appeared in literature.

Corythucha immaculata Osborn and Drake.

Corythucha pura Gibson is a synonym of this species. My long series of specimens from Montana connect up the two forms perfectly and *pura* cannot be considered even a variety of *immaculata*. The primary food plant is *Balsamorhiza sagittata*.

Corythucha morrilli Osborn and Drake.

A common insect in Texas, Arizona, New Mexico, Colorado, California and northern Mexico. Specimens at hand bear the food plant labels "on desert plant" and "on *Helianthus*." Morrill collected specimens on beans at Yuma, Arizona. *Morrilli* is somewhat variable in size, height and width of hood, and color. *C. mexicana* Gibson is very close to the larger specimens of *morrilli* and it may prove to be identical or a variety of *morrilli*. Both insects are much alike in color pattern.

Corythucha fuscigera Stal.

This insect has been much confused in literature with several other species. In examining the specimens in the National Museum and several other collections the writer found five or six different species under the name *fuscigera*. The distribution as given by Gibson (Trans. Am. Ent. Soc., Vol. XLVI, p. 78) includes records for other forms and the insect does not range from New Jersey to Colorado. Specimens have been examined from Arizona, Mexico and Central America. Champion gives a good figure of *fuscigera* in the Biologia Centrali-Americana and it is not readily compounded with other species.

Monanthia (?) necopina, new species.

Pronotum coarsely punctate, tricarinate, the carinæ rather thick and parallel, each with a single series of very small areolæ. Median carina raised in front, forming a small rather flat hood, the lateral carinæ ending anteriorly at the base of this hood. Paranota narrow, long, composed of mostly three rows of very small areolæ. Bucculæ closed in front. Head with five rather slender, moderately long spines. Antennæ rather stout, long; first segment thicker and a little longer than the second; third segment a little thinner than the second, a little more than two and a half times the length of the fourth; fourth segment slightly enlarged towards the apex. Antenniferous tubercles moderately large. Rostral groove uninterrupted, the rostrum extending slightly beyond the mesometasternal suture. Legs rather stout. Elytra extending beyond the apex of the abdomen, the areolæ very small; discoidal area marked off with strongly raised nervures, very long, reaching almost to the apex of the abdomen (about three-fourths of the total length of the elytra); costal area almost entirely triseriate; subcostal area with from two to three rows of areolæ, the areolæ of costal, subcostal and discoidal areas about equal in size; sutural area with the inner and distal cells becoming a little larger. Length, 3.1 mm.; width, 1.23 mm.

Color: General color light yellowish brown with a few of the veinlets brown or fuscous. Body beneath reddish brown, the thorax, coxæ, trochanters and femora darker. Tarsi and rostral laminæ tinged with yellowish. Head and prothorax on each side of the hood in front black, the spines on the head whitish. Antennæ with the basal and second segments dark brown, the third segment light brown and the fourth blackish.

One specimen, bearing the labels Bladensburg, Md., July 27, 1890, and P. R. Uhler Collection. The insect is so very distinct from any described North American tingid that I feel entirely safe in describing the species from a single specimen. The species does not seem to be congeneric with the American species of the genus *Monanthia* and I will take up its generic position in a subsequent paper.

Leptoypha ilicis, new species.

Small, narrowly oblong, slightly constricted at the base and near the apex of the elytra, and a little narrowed behind. Surface coarsely punctured. Pronotum with median carina fairly distinct, the lateral carinæ not traceable, even on the posterior extension. Antennæ short, first and second segments subequal, third equal to the length of the other three taken together, fourth a little shorter than the first and second conjoined. Spines on front of vertex arranged as in *L. mutica* Say, the decumbent spines from back of vertex usually a little shorter. Elytra with the areolæ in subcostal area arranged in four rows (in two or three specimens scarcely more than three), the costal area with only a few distinct cells at the constriction near the apex.

General color reddish brown, usually with blackish or fuscous areas. Legs with the tarsi fuscous. Body beneath dark reddish brown. Eyes black in fully matured specimens. Collar and apex of triangular portion of pronotum sometimes paler. In some specimens a few of the veinlets are infuscate.

Length, 2.21 mm.; width, .87 mm. Length of antennal segments; 1, .1 mm.; 2, .1 mm.; 3, .36 mm.; 4, .16 mm.

Described from numerous males and females, taken on Stone Mt., Georgia, June 8, 1917. The specimens were collected on Holly, *Ilex* sp., in company with a few specimens of *L. elliptica* McAtee by Mr. H. H. Knight. *Type* (male) and *allotype* (female). The insect is most closely related to *L. mutica* Say from which it may be separated by its much smaller size, and shorter antennæ. Long series of *mutica* from various parts of eastern United States fail to show any intermediate forms between the two species.

Acanthocheila exquisita Uhler.

Uhler's types of *exquisita* are in the late Heidemann Collection, Cornell University, Ithaca, New York.

COMPARATIVE TRANSPIRATION OF TOBACCO AND MULLEIN.

J. D. Sayre.

Comparative studies of the transpiration rates of Tobacco and Mullein have been carried on during the winters of 1917 and 1918 in the Ohio State University Botanical Greenhouse and Laboratory under the direction of Dr. E. N. Transeau. These experiments were performed with special apparatus designed by him and described in the *Botanical Gazette*, Vol. 52, on pages 54 to 60. By means of this apparatus it is possible to obtain a continuous record of the water loss from sealed potted plants. As many as six different plants can be used at one time.

Continuous records of the common environmental factors influencing transpiration were also obtained by the use of recording instruments; temperature, humidity, duration of sunshine, evaporation and wind velocity. From these records of transpiration from the plants and of variations in the environmental factors, certain conclusions have been drawn concerning the relation of the hairy coverings on the mullein leaves to the resistance of the plant water loss, the relation of the stomata to transpiration, and the daily rhythm of the transpiration curve. Figure 1 shows the results of one of the experiments which was performed in the greenhouse. These curves show the method of expressing the results. The details and records are contained in a paper to be published elsewhere.

When compared with a similar thin-leafed tobacco plant (*Nicotina* sp.) the following conclusions regarding the resistance of the mullein leaves (*Verbascum thapsus*) to transpiration were obtained.

1. Mullein leaves offer greater resistance to water loss in darkness than in light.

2. Mullein leaves offer less resistance to water loss in wind than in still air.

3. Mullein leaves respond as much or more to changes in the environment as to tobacco leaves.

When compared with another individual of the same species, the removal of the hairs from mullein leaves produced the following effects:

4. The removal of the hairs from the mullein leaves does not alter the resistance of the leaves to water loss in still air and light.

5. The removal of the hairs slightly decreases the resistance of the leaves to water loss in wind and light when compared with still air and light because the cuticular surface is more exposed to the air.

6. The removal of the hairs greatly decreases the resistance of the water loss in still air and darkness as compared with still air and light, due to the cuticular surface being more exposed, because the water loss in darkness is entirely from the external surface, the stomata being closed.

7. Hairs as "protective" covering against ordinary intensities of wind and light on mullein may be disregarded. The water loss from the leaves is mostly from the internal (mesophyll) surface of the leaves and not from the external hairy surface. The internal water loss is from twenty to forty times greater than the external or cuticular water loss. The removal of the hairs increases total transpiration only to the extent that the cuticular surface is more exposed, and has apparently no effect on stomatal transpiration.

A record of the size of the pore openings of the stomata was obtained by measuring camera lucida drawings of the pores. The drawings were made from small pieces of epidermis from a plant which was under the same conditions as those used in the measurement of the water loss. Small pieces of the epidermis were stripped from the under side of the leaf and immediately put in absolute alcohol. Samples of the epidermis for different hours of the day were treated in this way, and later mounted in absolute alcohol and a representative number of the pore openings quickly drawn on white paper under the high power of a microscope with the aid of a camera lucida. These drawings were measured and the figures reduced to their actual size in microns. The results were expressed both in terms of the total area, (square microns) and in terms of the length of the peripheries (microns) of the pore openings. Curves of these values were then plotted for the day on cross section paper.

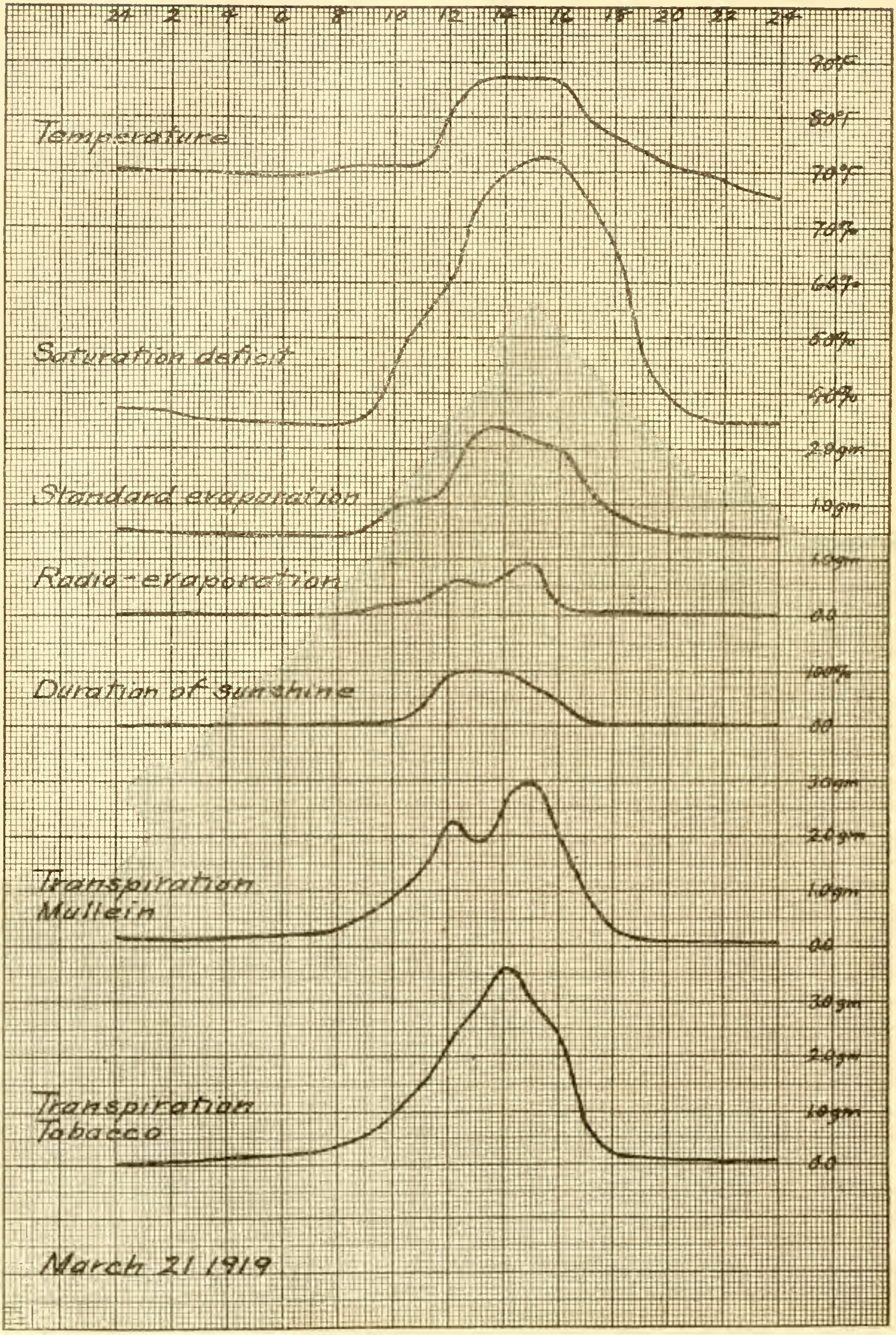

Fig. 1. Curves from one of the experiments showing the daily variation in the transpiration in tobacco and mullein and the variations in the environmental factor for the same period.

The total water content of leaves for each hour of the day from a similar plant was obtained by removing leaves at the different hours and determining their water content by weighing and drying to constant weight.

A curve was then plotted for each of the following factors: temperature, saturation deficit, evaporation, duration of sunshine, leaf water deficit, area of stoma, periphery of stoma, and the transpiration of the plant. The ordinates for each of these curves were reduced to the same scale and the transpiration curve was superimposed over each of the other curves. This makes possible a comparison of the different limiting factors controlling transpiration from muellin and tobacco.

These records show that the differences between the night and day rates of water loss from mullein and tobacco are largely due to the diffusion of water vapor through the stomatal pores. Transpiration from the leaf at night is cuticular and the rate is controlled by the temperature and humidity of the air. But the day rate is controlled by several factors operating to increase or decrease the rate. When the stomata open, the diffusion gradient (the difference between the intercellular saturation and atmospheric saturation deficit) causes a sudden rise in the rate of water loss. This rate continues until the leaf water deficit decreases the diffusion gradient by increasing the resistance of the mesophyll cells to water loss. After the leaf water deficit reaches a certain point (about noon) there are two factors, leaf water deficit and decreasing stomatal pores, operating to reduce water loss and only one factor, diffusion gradient, tending to increase it. This results in a rounded curve. After the saturation deficit reaches a maximum there are three factors, decreasing diffusion gradient, decreasing stomatal pores, and leaf water deficit, operating to reduce water loss with none of the factors opposing them. A rapid decline in the rate of water loss from the plant follows and the night rate is reached before the stomata are fully closed.

While performing the experiments on the relation of hairy coverings to the resistance of the leaf to water loss, a rhythm in the transpiration curve was noticed in certain cases where a plant was placed in the dark room and allowed to remain in total darkness during the following day. This rhythm was shown by a rise in the transpiration curve at the time the stomata usually opens at daybreak. It reaches a maximum about the middle of the forenoon and falls back to the normal night rate at about noon, although the plants were under conditions of constant temperature, saturation deficit, evaporation and total darkness.

A number of experiments were performed which show the conditions under which this rhythm takes place. Tobacco and mullein show a rhythm in the transpiration curve in total darkness when preceded by a day of normal light conditions, while moth mullein under the same conditions does not show this rhythm. This rhythm in tobacco and mullein does not take place on the second day in the dark room. In tobacco this rhythm does not take place on the following day unless the plant is placed in the dark room before noon. It seems, therefore, that this rhythm is due to some definite internal condition and that certain plants show it while others do not. Different plants were used in each experiment and all the plants of a given species agreed in their behavior. The cause of this rhythm is most likely in stomatal activity, but because of the large errors in measuring stomatal movements as compared with the small movement that is necessary to produce this rhythm this fact has not been satisfactorily established.

CORRECTION.

In the November, 1918, Journal of Science, Vol. XIX, No. 1, p. 61, in the second paragraph and the second line of the paragraph for the word "family" read "class *Edrioasteroidea*, Billings."

On page 77, in the next to the last paragraph, the citation from Bather is a mistake of the author's. Mr. Bather does not hold the views there ascribed to him. I have Mr. Bather to thank for these important corrections.

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Oxford, Ohio.

Date of Publication, May 25, 1919.

THE FAUNA OF ROCK BOTTOM PONDS.*

Frederic H. Krecker.

TABLE OF CONTENTS.

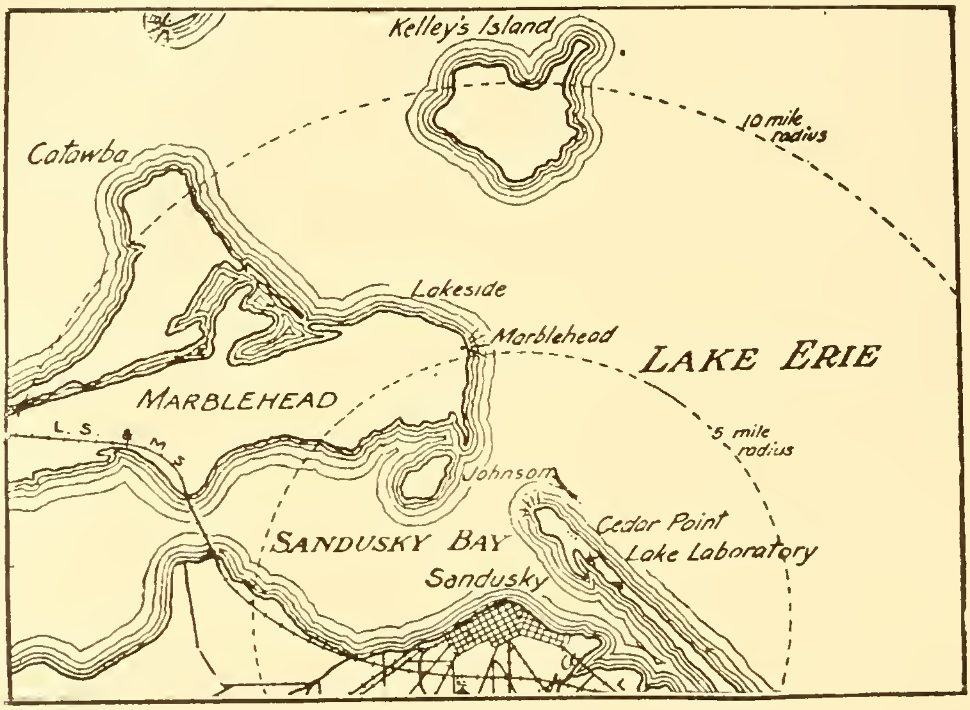
INTRODUCTION.

This investigation was undertaken for the purpose of studying the fauna and also the physical changes in a series of rock bottom ponds successively greater in age. Although ponds of various types have been studied, either individually or with a view to determining the succession of life in a series of different ages, so far as I am aware no one has studied a group which originated on a substratum of bare rock.

The ponds in question are in a number of limestone quarries near Sandusky, Ohio. Within a radius of fifteen miles there is a series of five ponds which at the time of the investigation were one, five, ten, fifteen and thirty years old respectively. They were formed as the result of striking water in the course of

* Contribution from the Department of Zoology and Entomology, Ohio State University No. 58.

quarrying operations. The thirty year pond is in the grounds of the Soldiers' Home on the southern outskirts of Sandusky. The two-year and the ten-year ponds are about half a mile beyond this and within one hundred yards of each other. The five-year pond is about five miles from Sandusky on Marblehead peninsula and within one hundred yards of Lake Erie. The fifteen-year pond is on Kelley's Island approximately twelve miles from Sandusky and four miles off shore in Lake Erie. The relative location of the series can be seen by referring to the map of the region on this page.



Map of the Region.

These ponds were under observation for four summers but the detailed work on which this article is based was done during the summers of 1916 and 1917. The seasonal succession is, therefore, not considered. However, summer is the season when in general the animals of a given habitat are most in evidence and the results given here are in all likelihood thoroughly representative.

In studying a given pond it was first examined as a whole and then certain definitely delimited areas typical of its various environments were studied intensively. In order to gain a concrete idea of the abundance of a given species all individuals taken in certain small areas were counted. Because of difficulties with the more active individuals these numbers are not absolutely accurate in all cases. They are a fairly close approximation, however, and are given in the belief that they serve to present a better idea of numbers than the terms "scarce," "common," "abundant," "numerous" and "few" which are relative and depend largely on the individual using them. For various reasons it was not possible to carry out this method at all times. When it had to be omitted numbers have either been indicated by the more relative method or they have been left out entirely. For determining the numerical quantity of plankton species, five samples were taken out of the total quantity derived from 100 liters of water and a count was made from each sample with the Sedgewick-Rafter cell.

The apparatus and methods used in collecting do not require extensive mention. A convenient field outfit for determining carbon dioxide was loaned by Prof. Foulk of Ohio State University. To determine the transparency of the water a porcelain lined top from an ordinary glass fruit jar was used. A simple dredge and several small nets were constantly needed.

In plankton collection tow nets were used when merely a sample was desired. These nets were maintained at a given level, whether at the surface or any number of feet below the surface, by means of a float which consisted of a small, tightly closed tin can. For quantitative plankton work a small hand pump of the type frequently employed in spraying was used. One method of operation was to pump water into a vessel of known capacity and then empty this into a net which was suspended in the pond. Another way was to pump directly into the net suspended in a vessel filled with water. The water then flowed from this into a vessel of known capacity. The first method seemed to give more accurate results for, unless the stream of water from the pump issued with very little force, some plankton forms were driven through the net. Either of these methods makes it possible to measure the exact amount of water passing through the net and avoids the possible error which may arise in the use of a plankton net or even of a calibrated pump.

For obtaining water from levels several feet below the surface a garden hose was attached to the pump. White rings were painted on it at intervals of a foot to facilitate the determination of the depth at which the pumping was to be made.

A stone was tied to the end of the hose to prevent sagging. This stone was also so arranged that if water were to be pumped from the bottom, the stone was between the end of the hose and the bottom. In this way there was less likelihood of drawing up sediment.

In presenting the results of the survey I shall first of all take up the ponds separately and in the order of their age beginning with the youngest. This will then be followed by a more general comparison and discussion of the results.

I wish to thank Prof. Foulk for the use of apparatus and Prof. Barrows of Ohio State University for the identification of spiders I also desire to acknowledge my indebtedness to a number of students who have been of assistance to me. I am particularly grateful to my wife for her constant aid.

ONE YEAR POND.

Pond I.

All of this pond was not, strictly speaking, only a year old since one corner of it covered a small pool in which water had collected while the quarry was still in operation. The greater part of it, however, was formed within a year of the time when it was examined. Taken as a whole it thus represents an extremely youthful stage in pond development. What might be termed the ancestral pool did not present a continuous habitat for aquatic forms since it was frequently emptied and was constantly kept under control by means of a steam pump.

Up to the autumn of 1916 the quarry was in active operation. It was then abandoned and by the summer of 1917 a pond 500 feet long and 150 feet wide had developed. Over most of it the water was from eighteen inches to three feet deep; over a restricted area it was as much as eight feet deep. The entire shore was of bare rock. On the east, west and north this rose up perpendicularly for 25 feet; along the south it rose 10 to 15 feet above the level of the water. The pond was surrounded on three sides by cultivated fields and on the fourth it was bordered by a gravel strip which intervened between it and an adjoining quarry. The photograph on page 431 gives an accurate idea of the pond and its surroundings.

The water was blue with a tinge of green. It was sufficiently transparent for the bottom to be seen anywhere. Its temperature just beneath the surface was 28° C. In the deepest water the bottom temperature was 26° C. In the shallower regions there was no difference between surface and bottom temperatures.

Vegetation was confined to filamentous algæ. These were everywhere abundant and usually extended to the bottom. Along most of the shore they were so thick as to form a dense mat on the surface. Decaying algæ were beginning to form organic sediment on the bottom which as yet was scarcely

Most of the One Year Pond is shown in this photograph.

measurable. There was approximately a quarter of an inch of inorganic sediment chiefly derived from the crushing of stone. Most of the larger stones had been cleared away but there were a few blocks at certain places. Details regarding these various features will be given in connection with the data from each of the stations.

Station 1. This station covered a triangular bay enclosed by a rock wall ten to twenty feet high which sheltered it from all sides except the south. It is to be seen in the far corner of the photograph on this page. The water was from six to eight feet deep. Near shore, in shallow water, there were a few millimeters of sediment. In the center there were in places three to four inches of rather mucky material which probably represented sediment from a wider area drawn together by the action of the drainage pump. Over this muck was a thick growth of *Chara* that had gained a foothold before the pond proper was formed. The accumulation of a sufficiently thick substratum for it to take root was undoubtedly hastened by the action of the pump. In with the *Chara* and reaching the surface were filamentous algæ.

The animals found at this station are given in Table 1.

TABLE 1.

Group	Species	Littoral Stones	Sediment on Bottom	In Algæ	Chara	Mud of Chara Root	Nekton	Beneath Algæ	Surface of Water	Remarks
Coleoptera Adults	Hydroporus mixtus	1	..	..	..	..	..	..	..	
	Dineutes assimilis	..	..	..	..	..	..	..	3000	Area 5′ x 100′
	Gyrinus aquiris	..	..	..	..	..	..	..		
	Tropisternus nimbatus	1	..	..	..	..	..	..	..	
	Coelambus laccophilinus	1	..	2	..	..	..	..	..	Algae near edge.
Coleoptera Larvæ	Dytiscidæ	2	..	m'y	2	..	..	..	..	
	Gyrinidæ	1	..	..	..	..	..	..	..	
	Haliplidæ	1	..	2	1	..	..	..	..	
	Hydrophilidæ	..	..	5	..	..	..	..	..	
	Lagriidæ	..	..	..	2	..	..	..	..	
Diptera Larvæ	Corethra	..	100	..	..	..	..	..	..	
	Metriocnemus	..	..	50	..	..	..	..	..	
Ephemeridæ Nymphs	Amelitus sp	..	2	..	1	..	..	..	..	
	Heptagenia variabilis	x	..	..	..	..	..	..	..	
	Caenis allecta	..	..	..	2	..	..	..	..	
Hemiptera	Notonecta insulata	..	..	..	..	..	15	..	x	5 adults, 10 nymphs
	Corisa	..	..	..	..	..	x	..	5	1 adult, 4 nymphs.
Sialididæ	Sialid larva	..	..	..	2	..	..	..	..	
Tricoptera	Leptocerid larva	..	3	..	..	..	..	..	..	
	Hydrospyche sp(?)	..	..	1	..	..	..	..	..	
Crustacea	Asellus attenuatus	..	3	..	6	..	..	..	..	
	Cypris sp	..	..	..	..	x	..	..	..	
	Cyclops	..	..	..	..	..	..	..	..	
	Nauplius (Cyclops)	..	..	..	..	..	x	..	..	
Mollusca	Physa heterostropha	5	..	25	2	3	..	20	..	Beneath algæ, 1′x1′ 15 large, 5 small. In algæ, 4 large, 21 small.
	Lymnaea humilis	..	..	1	1	..	..	..	..	
	Planorbis parvus	..	..	..	3	..	..	..	..	
Annelida	Glossiphonia stagnalis	5	..	..	1	7	..	..	..	
Total number of species		9	4	8	11	3	2	1	3	

The figures in this table represent the number of individuals taken in an area 12 inches by 24 inches, except as otherwise indicated.

It will be seen from the table that, of the different habitats given, *Chara* had the greatest number of distinct species. The stones along the water's edge and the algæ floating free in the water had, in turn, the next greatest number of inhabitants. The bottom and pelagic habitats had the fewest forms. The relative positions of the old and the young *Physæ* and also of the nymphal and adult *Notonecta* are interesting. As indicated in the table the young *Physæ* were almost exclusively on the filamentous algæ suspended in the water. On the other hand the older and larger individuals were chiefly on the semi-mucky material beneath the algæ. The nymphs of *Notonecta* were likewise in the algæ. They were most numerous in some which rested on a ledge about six inches below the surface. The leech, *Glossiphonia stagnalis*, was particularly abundant on *Chara*.

Station 2 of Pond I.

The gyrinid beetles were unusually numerous; one hundred of them were counted in a strip three inches wide and five feet long. In a strip five feet wide and one hundred feet long I estimated that there were 3,000. Most of those within the area covered by Station 1 were collected in this strip. It was noticeable that the beetles were not abundant over the main portion of the pond beyond the shelter afforded from strong breezes by the high walls enclosing the station.

Station 2. The section of the quarry included in this station was not covered with water until within less than a year of the time it was studied. It is interesting because it was within 250 feet of Station 1, parts of which had been intermittently submerged for a longer period. The photograph on page 433 indicates the character of the situation. It was typical of the conditions along the east side of the pond. The shore was perfectly bare rock. The water was between three and four feet deep and contained an abundant growth of algæ.

Table 2 presents a list of the species found in this region.

TABLE 2.

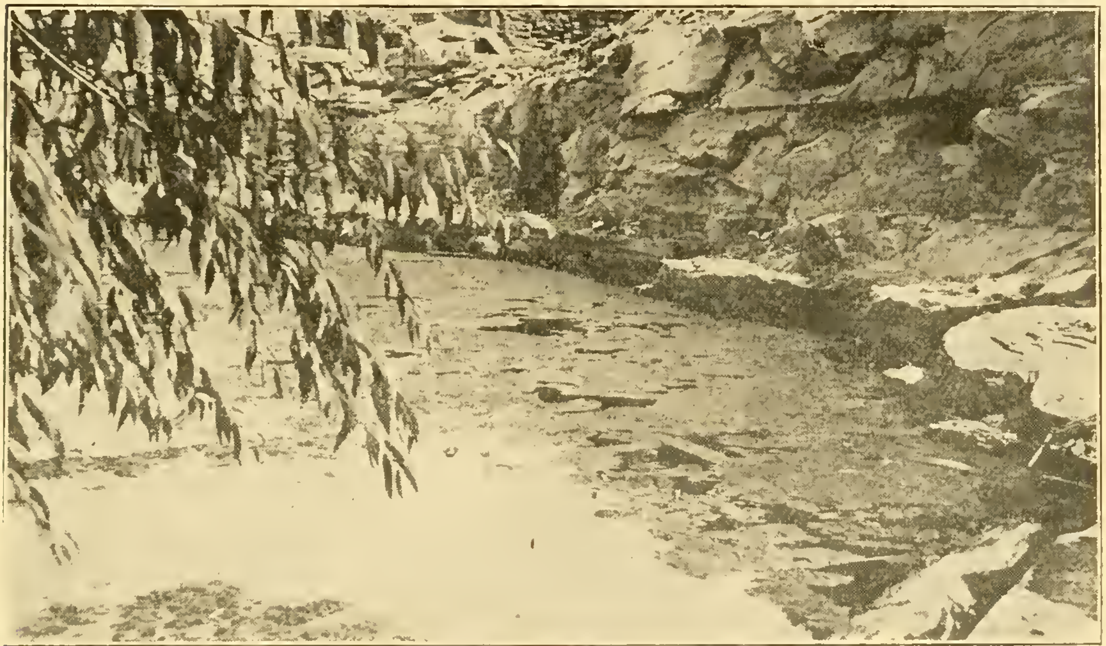
Group	Species	Algæ	Littoral Stones	Stones Beyond Littoral	Nekton	Surface Water	Sediment on Bottom
Coleoptera Adults	Hydroporus mixtus	....	x	....	....	....	....
	Hydroporus concinnus	....	x	....	....	....	....
	Agabus disintegratus	....	x	....	....	....	....
	Coelambus laccophilinus	....	x	....	....	....	....
	Dineutes assimilis	....	....	....	x	x	....
Coleoptera Larvæ	Dytiscidæ	x	x	x	....	....	....
	Gyrinidæ	....	....	x	....	....	....
	Hydrophilidæ	x	x	....	....	....	....
Diptera	Chironomus sp	....	....	....	....	....	x
Ephemeridæ	Heptagenia variabilis	....	x	x	....	....	....
Hemiptera	Notonecta insulata	....	....	....	x	x	....
	Corisa	....	....	....	x	x	....
Crustacea	Cyclops, Nauplius	....	....	....	x	....	....
Arachnida	Limnochares aquaticus	....	....	....	x	....	....
Mollusca	Lymnaea humilis	x	x	x	....	....	....
	Physa heterostropha	x	x	....	....	....	....
	Planorbis parvus	....	....	x	....	....	....
Annelida	Glossiphonia stagnalis	....	x	x	....	....	....
Total number of species		4	10	6	4	3	1

The total number of species for Station 2 is markedly fewer than it was at Station 1. There were no *Tricoptera* or *Sialididæ.* The species of coleopterous larvæ were fewer, although adult species were more numerous. Under the circumstances we would of course expect larval forms to be at least less common if not entirely absent. The mere fact that larvæ were present does not of necessity mean they had developed here from the egg, since they might have migrated from Station 1.

The greatest variety of species was found among stones in the littoral zone. At Station 1 this zone came next to the *Chara* in point of numbers, which were one less than at Station 2. No record was made at this station of the number of individuals for each species. However, two counts of *Physæ* were taken.

In one littoral situation, stony and with abundance of filamentous algæ, there were twenty-five *Physæ* in an area 6 x 4 x 5 inches. In another somewhat similar situation there were fifty-one in a space 2 x 5 x 3 inches. Most of them were young which was also true of those found in the algæ at Station 1. *Notonecta* were likewise common.

Station 3. This was 500 hundred feet distant from Station 1 and covered that portion of the pond farthest away from the region of the original pool. It was one of the last portions to



Station 3 of Pond 1.

be covered with water. The sides of the quarry rose up twenty-five feet and as elsewhere they were entirely devoid of vegetation. The conditions are shown in photograph above.

The water was not more than eighteen inches deep. In it there was a rich growth of filamentous algæ from bottom to surface. That on the surface formed a thick mat which in places extended twenty-five to thirty feet out from shore. It was more abundant here than anywhere else in the pond. On the bottom there was an inorganic sediment, chiefly quarry dust, one-eighth of an inch thick. Dead and decaying algæ were establishing the beginning of an organic deposit. In some places the partly decomposed algal material was a quarter of an inch thick. This amount, of course, would tend to diminish as decomposition became more complete.

The animals inhabiting the area are given in Table 3, below. There is a marked decrease in the number of species found here as compared with the list in Table 2. Most of the reductions come in the coleoptera; only two species of these were found, both of them adults. The absence of the surface beetles such as the gyrinids, so abundant at the opposite end of the pond, was noticeable and is apparently to be correlated with the great amount of filamentous algæ present, the mat it formed clearly making locomotion difficult. The *Notonecta* were also scarce and in this instance, likewise, the algæ probably offered a hindrance to their free locomotion.

TABLE 3.

Group	Species	Littoral	Algæ	Stones Beyond Littoral	Sediment on Bottom	Nekton
Coleoptera	Hydroporus mixtus	2	....	....	....	....
	Philhydrus ochraceus	4	....	....	....	....
Diptera Larvæ	Chironomus sp	....	....	....	50	....
	Tanypus sp	....	....	....	30	....
Ephemeridæ	Ephemerella excurcians	6	....	9	....	....
Hemiptera	Notonecta insulata	....	....	....	....	4
Crustacea	Cyclops	....	....	....	....	....
	Nauplius	....	....	....	....	x
Mollusca	Lymnaea humilis	5	3	....	....	....
	Planorbis parvus	1	2	2	....	....
	Physa heterostropha	5	23	34	....	....
Annelida	Glossiphonia stagnalis	1	....	1	....	....
Total number of species		7	3	4	2	1

The figures in the table refer to the number of individuals found in an area 12 by 18 inches.

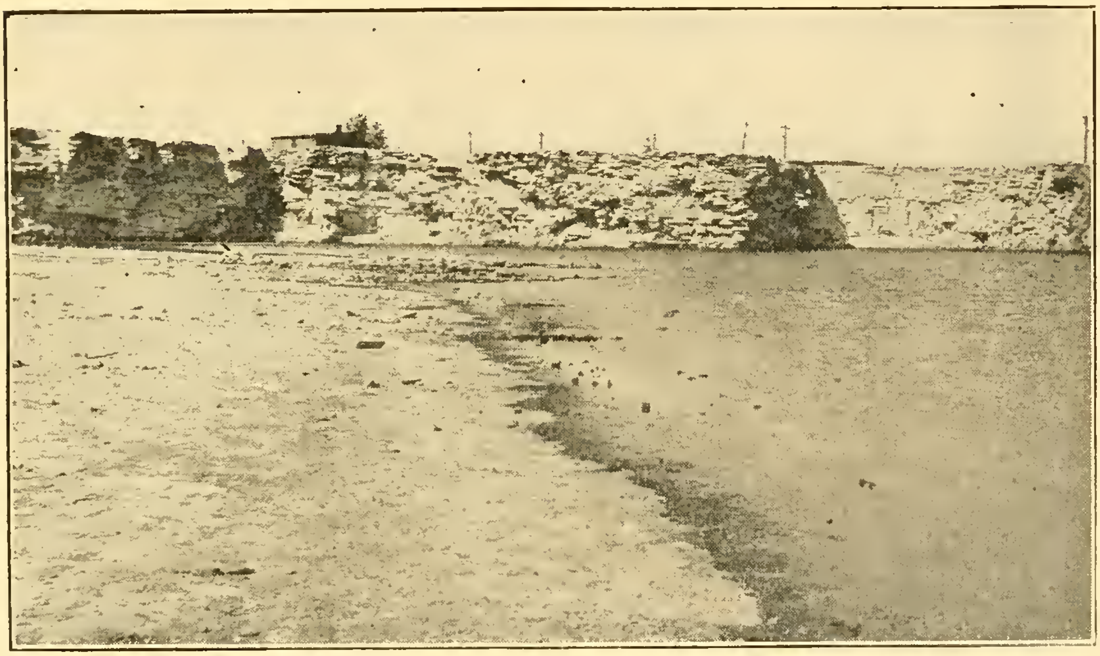
The thirty-four snails listed as coming from the stones beyond the littoral zone include some from the algæ. Here again the young snails were mostly in the algæ and the larger ones among the stones near the bottom.

Station 4. This station included the west side of the pond. It is shown on page 437. The floor of the quarry in this region gradually sloped beneath the water so that the depth of water was from a fraction of an inch along the edge to four or five inches fifty feet from shore. In the shallowest water there was practically no vegetation. In deeper water there were some filamentous algæ. On the bottom there were a few millimeters of organic sediment and also a few stones, most of them small.

The shallowest water offered a rather uncertain habitat, since even a very slight lowering of the general water level would lay the bottom bare, and, indeed, even without such an occurrence, the depth of water was hardly sufficient to accommodate any but the smallest animals.

The number of species found is the same as for Station 3 but the species differ. They are given in Table 4, page 438.

No general counts were made. On the whole, however, there were very few individuals of any one species. With the reduction in the amount of algæ, gyrinid beetles were again present where the water was deep enough for their maneuvers.



Station 4 of Pond I.

In the precarious littoral zone there were few species and also few individuals. In ten linear feet only five *Physæ* were observed and only one hybrobatid, *Gerris*, was seen in twice that distance. The scarcity of algæ was one reason for the comparatively few *Physæ*. Here and there patches of filamentous algæ were present and near these spots *Physæ* and also *Hydroporus* were noticed. I observed two or three sandpipers running along the water's edge. This bird was apparently quite a frequent visitor since its footprints were numerous.

Plankton. The plankton material taken in the summer of 1917 was accidentally destroyed. Material was again obtained in July, 1918. Although this does not represent conditions as they were at the end of the first year, still it does represent an early stage in the plankton of a rock enclosed pond and for that reason I shall include it. The forms found most frequently are given in Table 5. The figures placed in line with each type represent, first the quantity in 100 liters of water and, following this, the percentage of the total catch which it represents. A glance at the table will show that any species not included were practically negligible so far as numbers are concerned.

TABLE 4.

Group	Species	Littoral	Stones Beyond Littoral	Algæ	Sediment on Bottom	Surface of Water
Coleoptera	Hydroporus mixtus	x	....	x	....	....
	Dineutes assimilis	....	....	....	....	x
	Gyrinus aquiris	....	....	....	....	x
Diptera Larvæ	Chironomus sp	....	x	....	x	....
	Tanypus sp	....	....	....	x	....
Ephmeridæ	Ephemerella excurcians larva	....	x	....	....	....
Hemiptera	Gerris conformis	....	....	....	....	x
Mollusca	Physa heterostropha	x	x	....	....	....
	Eggs of Physa	....	x	....	....	....
Annelida	Glossiphonia stagnalis	....	x	....	....	....
Vertebrata	Sandpiper	x	....	....	....	....
Total number of species		3	5	1	2	3

The figures for *Dinobryon* represent colonies. In addition to these there were a great many separated individuals which are not included in the count. The enormous number of colonies is interesting in view of the time of year at which they were obtained and the temperature of the water. They are ordinarily considered to be abundant in the cooler months of the year or, at least in cooler waters. This catch was taken in the middle of July from water of 28° C.

Discussion. Two prominent features of the association in this pond are (a) the entire absence of fish or any other aquatic vertebrate and (b) the preponderance of its insect population. The absence of fish was primarily due to the fact that none had yet been introduced by man. The large insect population was very probably correlated with the fact that no fish were present, especially so the great abundance of pelagic forms such as *Notonecta* and *Gyrinus*. The pond seemed to offer optimum conditions for both of these species. In all the deeper regions the water was thickly populated with *Notonecta* from surface to bottom and in certain protected areas *Gyrinus* was equally numerous.

All of the species found in the pond are given in Table 6, page 440. A glance at the totals for each station will show that there was a progressive reduction in the number of the species as the distance from the parent pool, *i. e.*, Station 1, increased. This indicates a correlation between the age of the various parts of the pond and the number of inhabitants present. It also throws some light on the rate at which forms take possession of new and unoccupied habitats with which there is an unbroken medium of communication from a region already inhabited.

TABLE 5.

QUANTITATIVE PLANKTON RESULTS.

Species	Number per 100 Liters	Per Cent of Total
Ceratium	850,000	39.
Dinobryon	1,325,000	60.
Arcella	4,000	.0018
Rotifera	4,500	.002
Nauplius	15,625	.007

As might be expected the adult forms were more generally distributed than were the larval stages. This is especially noticeable with the coleoptera. Beyond Station 2 larval beetles were entirely absent. Among the diptera and ephemeridæ there was an uneven distribution of species. Larval representatives of these groups found at Station 1 were not present at Stations 2 and 3, and vice versa. Distribution of this sort is the result of entirely new colonization in the different localities and has no relation to migration within the pond.

In general, of the larger and more active or powerful adult forms in the region of the parent pool, seven out of eleven were found also at three or more of the four stations. Of similar forms present at only one or two stations there was an even division between those found at the parent pool and those that were not. Apparently, then, the adult population of the parent pool was well represented over the entire pond. The cases of localized distribution of adults were due to fresh colonization in the newer parts of the pond rather than to slow or capricious migration from the original pool.

There were two well defined instances of distribution being influenced by unlike food habits at different ages. One of these was shown by *Physa* which exhibited a very clear stratification and the other case was the relation of nymphal *Notonecta* and algæ. In this instance, however, there was no stratification.

TABLE 6.

Group	Species	Station 1	Station 2	Station 3	Station 4
Coleoptera Adults	Hydroporus mixtus	x	x	x	x
	Hydroporus concinnus	..	x	..	..
	Tropisternus nimbatus	x	..	..	..
	Philhydrus ochraceus	..	..	x	..
	Dineutes assimilis	x	x	..	x
	Agabus disintegratus	..	x	..	..
	Coelambus laccophilinus	x	x	..	..
	Gyrinus aquiris	x	..	..	x
Coleoptera Larvæ	Dytiscidæ	x	x	..	..
	Gyrinidæ	x	x	..	..
	Hydrophilidæ	x	x	..	..
	Haliplidæ	x	..	..	..
	Lagriidæ	x	..	..	..
Diptera Larvæ	Corethra sp	x	..	..	..
	Metriocnemus sp	x	..	..	..
	Chironomus sp	..	x	x	x
	Tanypus sp	..	..	x	x
Ephemeridæ Nymphs	Heptagenia variabiis	x	x	..	x
	Amelitus sp	x	..	..	..
	Caenis allecta	x	..	..	..
	Ephemerella excurcians	..	..	x	x
Tricoptera	Leptocerid larva	x	..	..	..
	Hydrospyche sp?.	x	..	..	..
Hemiptera	Notonecta insulata	x	x	x	..
	Corisa	x	x	..	..
	Gerris conformis	..	..	..	x
Sialididæ	Sialid larva	x	..	..	..
Arachnida	Limnochares aquaticus	..	x	..	..
	Pirata fibriculosa	x	..	..	..
Crustacea	Asellus attenuatus	x	..	..	..
	Cyclops sp	x	x	x	..
	Nauplius (Cyclops)	x	x	x	..
	Cypris sp	x	..	..	..
Mollusca	Physa heterostropha	x	x	x	x
	Eggs of Physa	..	..	..	x
	Lymnaea humilis	x	x	x	..
	Planorbis parvus	x	x	x	..
Annelida	Glossiphonia stagnalis	x	x	x	x
Vertebrata	Sandpiper	..	..	..	x
Total number of species		26	17	10	11

FIVE YEAR POND.

Pond II.

The five-year pond is on Marblehead peninsula, approximately one hundred yards from Lake Erie. It fills a rectangular depression in the solid rock of an abandoned quarry. This is the largest of the five ponds, its sides measuring 300, 250, 500 and 450 feet respectively. The quarry as a whole has been excavated from fifteen to twenty feet below the surface of the surrounding land. The pond is separated from the limits of

Station 1 of Pond II.

this excavation on three sides by a strip of quarry bed twenty-five to fifty feet wide. This was partly overgrown by grasses and weeds. On the remaining side the quarry bed stretches away for almost a hundred yards with only here and there a growth of vegetation. There are abandoned lime kilns at one point. In front of these the shore is made up of soft residue from the kilns. This is the only break in the solid rock enclosing the pond. In one corner the water extended out over this rock and formed several pools.

Most of the pond was between eight and nine feet deep with a maximum depth of thirteen feet and eight inches. The water was blue with a slight tinge of green. The transparency disk was visible for nine feet and three and one-half inches. The temperature of the water just beneath the surface was 28° C. At a depth of five feet it was 27° C. and ten feet down it was 21° C.

STATION 1. The character of this station is shown on page 441. The side of the pond was a perpendicular face of practically bare rock. The water was between eight and nine feet deep. The only sign of vegetation was a sparse growth of filamentous algæ on the rock. On the bottom there was about one-fourth inch of sediment composed chiefly of quarry dust.

The species at this station are given in Table 7, below. The plankton and the nekton are not included, these being treated at another place for the whole pond. It will be seen that the number of forms was decidedly limited, although individuals were numerous in some cases as, for instance, the nematodes

TABLE 7.

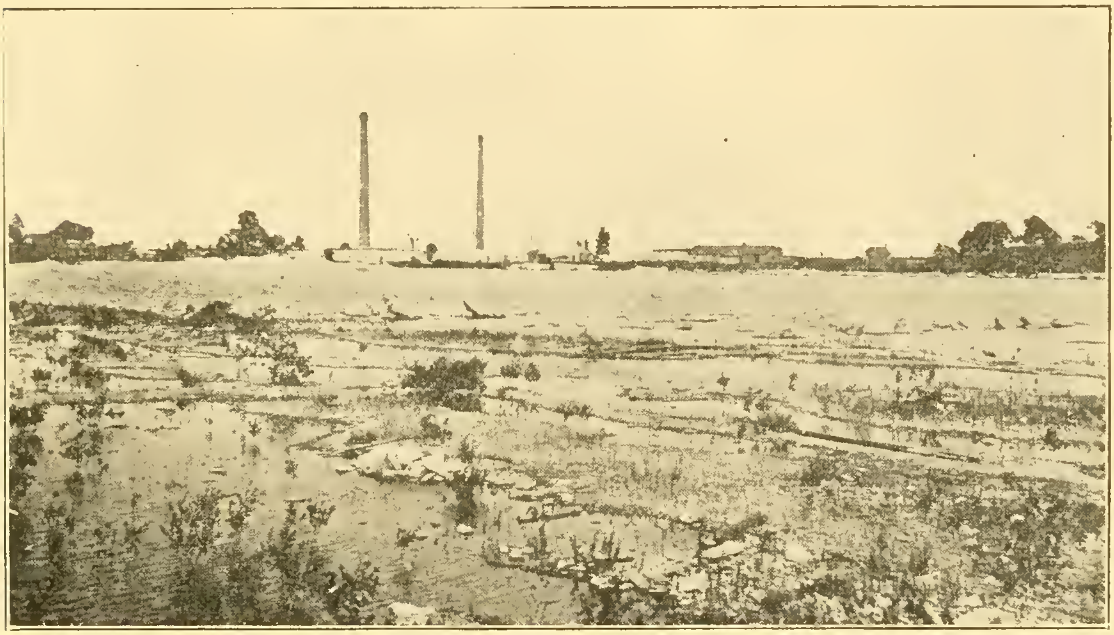
GROUP	SPECIES	Algæ	Sediment	Bare Rock Bottom
Diptera Larvæ	Tanypus sp? Chironomus sp?	x x	.. ..	.. ..
Entomostraca	Cypridopsis vidua	..	x	..
Annelida	Nais elinguis	..	x	..
Nemathelminthes	Nematoda	..	x	..
Protozoa	Vorticella sp?	..	...	x

and the larvæ of the midges *Chironomus* and *Tanypus*. The entomostracan, *Cypridopsis vidua*, was also found in abundance. *Nais* was scarce and so was *Vorticella*.

This station was characteristic of three-fourths of the shore line in its physical features as well as in its animals and plants. A similar environment on the opposite side of the pond, the far side in the photograph on page 448, differed in that at places the water was not as deep and the bottom was covered with rubble. In such locations the nests of sunfish were observed.

STATION 2. The pools shown in the foreground of the photograph on page 443 comprise this station. Some of these were directly connected with the pond; others were formed by water seeping through the intervening gravel. They were all shallow, the deepest having only five inches of water. A very slight change in the pond would obviously have wrought a great change in the pools. Unless otherwise indicated the conditions to be described will apply only to those pools directly connected with the pond.

The bottom was covered with pebbles, sand and chips of stone. The larger vegetation consisted chiefly of willow shoots. On the ridges between pools there was a miscellaneous scattering of grasses and weeds. Within the pools there were abundant growths of filamentous algæ.



Station 2 of Pond II.

Table 8, page 444, includes the forms from three pools. The species marked with an asterisk were all found in a pool broadly joined with the pond. Not all of these were in the other two pools.

Two-thirds of the snails were on the upper side of small stones. Most of them were young. They were far more abundant where algæ grew than they were on a bare substratum. In one pool containing algæ there were fifty-five *Physæ* in an area twelve by eighteen inches, whereas in a pool with practically no algæ there were only forty-five of them in an area seven feet by eighteen inches. Chironomid larvæ were present in great numbers. The Odonata were found near the edge of the pool among pebbles and sand.

STATION 3. This station covered the corner of the pond near the lime kilns. A portion of the shore is shown on page 445. A similar condition extended around to the right beyond the field of the picture. Refuse from the kilns had been dumped here and formed a substratum which, from an environmental standpoint, resembled a sandy beach. It was thoroughly soaked with water and in many places would not bear one's

TABLE 8.

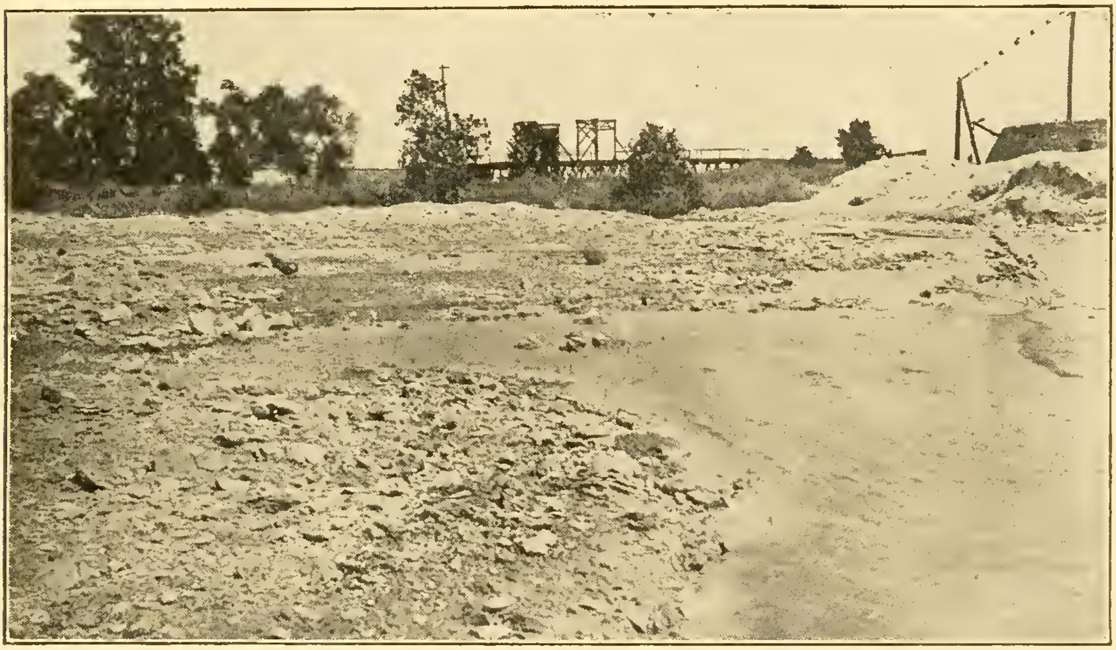
GROUP	INDIVIDUAL	Stones Upper side	Stones Lower side	Pebbles and Sand	Surface of Water	Edge of Pool	Algæ	Nekton	REMARKS
Coleoptera Adults	Agabus disintegratus*	..	..	..	..	1	..	..	
	Gyrinus aquiris	..	..	..	1	..	..	..	In whole pond.
	Stenus sp	..	..	..	..	1	..	..	12″ x 18″
	Peltodytes sp., larva*	..	..	1	..	..	..	..	
Odonata Nymphs	Tetragoneuria cynosura*	..	..	4	..	..	..	..	
	Pachydiplax longipennis*	..	..	1	..	..	..	..	
	Anomalagrion sp.*	..	..	6	..	..	..	..	
	Ischnura sp	..	..	x	..	..	..	..	
Diptera Larvæ	Chironomus sp.*	179		..	..	..	..	..	
	Chironomus sp	16		..	..	..	..	..	12″ x 18″
	Tanypus sp	..	21	..	..	..	..	..	
Ephemeridæ Larvæ	Caenis allecta*	..	65	..	..	..	..	..	
	Heptagenia variabilis	..	x	..	..	..	..	..	
Hemiptera	Gerris conformis	..	..	..	x	..	..	..	
Tricoptera	Limnophilus sp.*	..	2	..	..	..	..	..	
Mollusca	Physa heterostropha*	x	x	x	..	..	x	..	
	Eggs of Physa	..	15	..	..	..	..	..	
Crustacea	Cypridopsis vidua	..	..	..	..	..	..	x	
	Cyclops ater	..	..	..	..	..	..	x	
Coelenterata	Hydra fusca*	..	3	..	..	..	..	..	
Vertebrata	Minnow	..	..	..	..	..	..	x	
	Tadpole (Rana)	..	..	..	..	..	..	x	
Total number of species		3	9	6	2	2	1	4	

Numerals where given indicate the number of individuals in an area 7 by 12 feet, except as otherwise stated.
* See text for explanation of the asterisk.

weight. The water was shallow and the waves rasped the pebbles and finer particles about as sand is shifted by wave action. Such material is a very unsuitable habitat. The only vegetation consisted of the willow shoots and the bunch of grass shown in the photograph.

A few *Physæ* were scattered about where large stones gave them a firm footing. Here and there a few Chironomid larvæ were found and an occasional nymph of *Heptagenia variabilis*. Aside from these forms there were no animals in this area.

Station 4. The fourth station covered an area representing conditions in the central region of the pond, beginning at least fifty feet from shore. The particular section studied in detail was about one hundred feet off shore, midway between Stations 1 and 3. Its location is shown approximately by the position of the boat in the photograph on page 448. About one-fourth of the entire bottom in this region was covered by a rather thick growth of *Chara* which grew in a substratum of mud formed from quarry dust. The maximum thickness of this mud was



Station 3 of Pond II.

three to four inches. The bottom over the rest of the pond had a fine, silty deposit one-fourth to one-half inch thick and was without vegetation.

The animals taken from the bottom were about the same as those in the bottom sediment of Station 1. A list of them is given in Table 9, page 446. Here again the nematodes were numerous. Blood worms were quite abundant. Larvæ of the midge, *Corethra*, were also found. *Nais* was more common than at Station 1. An occasional *Difflugia corona* was observed.

Fish were numerous all over the pond except in the shallow pools of Station 2 and in most of the area covered by Station 3, which was also shallow. From persons acquainted with the history of the pond I learned that some fish were introduced not more than a year after the quarry filled with water. Bearing in mind the conditions in Pond I it is probably safe to assume that they found a large insect population to serve as a food supply. Other fish were thrown in from time to time. Nests present at the time of this survey afford good ground for concluding that the fish population has been continually increased by natural propagation.

TABLE 9.

Group	Species	Sediment	Chara mud	Nekton	Beneath Stones	Surface Tow	Deep Tow
Diptera Larvæ	Chironomus sp	x	..	..	..	..	..
	Corethra sp	..	x	..	..	..	..
Ephemeridæ	Heptagenia variabilis	..	..	..	x	..	..
Entomostracan Crustacea	Cypridopsis vidua	x	..	..	..	x	..
	Cypris sp	x	..	..	..	..	..
	Bosmina longirostris	..	..	..	..	x	x
	Daphnia sp	..	..	..	..	x	
	Chydorus sphaericus	..	..	..	..	x	x
	Cyclops ater	..	..	..	..	x	x
	Nauplius (cyclops)	..	..	..	..	x	x
Annelida	Nais elinguis	x	..	..	..	..	..
Rotifera	Proales decipiens	..	..	..	..	..	x
	Brachionus bakeri	..	..	..	..	..	x
	Dystila ludwigii	..	..	..	..	x	..
Nemathelminthes	Nematoda	x	x	..	..	..	..
Protozoa	Ceratium longicorne	..	..	..	..	x	x
	Difflugia corona	..	..	..	..	..	x
	Arcella	..	..	..	..	x	..
Vertebrata	Lepomis pallidus	..	..	x	..	..	..
	Eupomotis gibbosus	..	..	x	..	..	..
	Perca flavescens	..	..	x	..	..	..
	Apomotis cyanellus	..	..	x	..	..	..
Total Number of Species		5	2	4	1	9	8

In order to gain an idea of what the fish were eating the stomachs of five were examined. Their contents is given below:

1. Lepomis pallidus	Mayfly nymphs, 3. Filamentous algæ, small quantity.
2. Eupomotis gibbosus	Chironomus larvæ, 3. Filamentous algæ, small quantity. Beetles, 3; distinct species but undetermined.
3. Apomotis cyanellus	Tipulid larvæ, 8. Ichneumon (?), adult 1. Sialis larva, 1. Blue-Green algæ, considerable.

4. Perca flavescens	Dragon-fly nymph, 1. May-fly nymph, 1. Blue-Green algæ, small amount.
5. Apomotis cyanellus	Chironomus larvæ, 4. Beetle, 1. Filamentous algæ, small amount.

Plankton. The plankton results are given in Table 10, on this page. This represents conditions two feet below the surface. The species of *Rotifera* which are listed separately in Table 9 have been grouped together in this table. Towings, taken over a period of two years in the course of class work, gave results which are a sufficiently close approximation to those given here to indicate that these afford a representative idea of plankton conditions during mid-summer.

TABLE 10.

Plankton Quantitative Results.

Species	Number in 100 Liters	Per Cent of Total
Ceratium longicorne	203,125	90
Nauplius	7,500	3.3
Chaedorus sphaericus	6,696	2.9
Arcella vulgaris	6,250	2.9
Rotifera	2,231	.9

Discussion. A noteworthy feature of this pond is the almost total absence of insects from the greater part of it. In the list of all the forms, given in Table 11, page 449, no adult insects and only a few larval stages are credited to the deeper regions. Possibly at least a few representatives of the species named were present in these regions but they were at all events not noticeably common. In explanation of this state of affairs the fish must be considered. The pond was almost as thickly populated, proportionately, with fishes as was Pond I with *Notonecta* and gyrinids. The stomach contents of the fishes shows that a large part of their food was insects. The presence of appreciable numbers of insects in the shallow pools strikingly illustrates the faunal differences between waters that can be entered by fishes and those that can not.

Physical factors also had their influence on the character of the association. The smooth perpendicular face of rock offered a bleak and unattractive habitat for many animals normally to be found along the shores of ponds. The shore-inhabiting coleoptera and the odonata nymphs found in the pool region frequent situations which furnish protection either in the form of small stones and debris or in the form of a yielding substratum. Much the same holds true for ephemerid nymphs and such snails as *Physa*. It will be noted that both of these were represented at Station 3 which is that part of the main pond approaching suitable conditions for them.

A view of the Five Year Pond.
The shallow pools are not visible.

A pond in the state of development attained by this one is thus seen to offer an environment primarily suited to pelagic forms, and the animals actually inhabiting it are largely of this type. The total absence of pelagic insects, as previously pointed out, is to be attributed to the fishes. However, when we consider all of the pond, both shallow and deep waters, insects far outnumbered any other class. This statement is perhaps not entirely fair to the protozoa, a careful tabulation of which was not attempted. Aside from these microscopic animals the insects composed forty per cent of the total population.

TABLE 11.

SUMMARY OF SPECIES IN FIVE YEAR POND.

Group	Species	Station 1	Station 2	Station 3	Station 4
Coleoptera	Agabus disintegratus*	..	x	..	..
	Gyrinus aquiris*	..	x	..	..
	Stenus sp.*	..	x	..	..
	Peltodytes. larva*	..	x	..	..
Odonata Nymphs	Tetragoneuria cynosura	..	x	..	..
	Pachydiplax longipennis*	..	x	..	..
	Anomalagrion sp.*	..	x	..	..
	Ischnura sp.*	..	x	..	..
Diptera Larvæ	Chironomus sp	x	x	x	..
	Tanypus sp	x	x	..	..
	Corethra sp	..	..	..	x
	Chironomus sp	..	x	x	x
Ephemeridæ Larvæ	Caenis allecta*	..	x	..	..
	Heptagenia variabilis	..	x	x	x
Hemiptera	Gerris conformis	..	x	..	..
Tricoptera	Limnophilus sp. larva	..	x	..	..
Entomostracan Crustacea	Cypridopsis vidua	x	x	..	x
	Cyclops ater	..	x	..	x
	Cypris sp	..	..	..	x
	Bosmina longiristris	..	..	..	x
	Daphnia sp	..	..	..	x
	Chydorus sphaericus	..	..	..	x
	Nauplius (cyclops)	..	..	..	x
Mollusca	Physa heterostropha	..	x	x	..
	Eggs of Physa	..	x	..	..
Annelida	Nais elinguis	x	..	..	x
Rotifera	Distyla ludwigii	..	..	..	x
	Brachionus bakeri	..	..	..	x
	Proales decipiens	..	..	..	x
Nemathelminthes	Nematode	x	..	..	x
Coelenterata	Hydra fusca	..	x	..	..
Protozoa	Vorticella sp	x	..	..	..
	Difflugia corona	..	..	..	x
	Ceratium longicorne	..	..	..	x
	Arcella sp	..	..	..	x
Vertebrata	Lepomis pallidus	..	..	..	x
	Eupomotis gibbosus	..	..	..	x
	Perca flavescens	..	..	..	x
	Apomotis cyanellus	..	..	..	x
	Minnow	..	x	..	..
	Tadpole (Rana)	..	x	..	..
Total number of species		6	22	4	22

* Species found only in region of pools.

TEN YEAR POND.

Pond III.

The ten-year pond is a rock-bound basin 140 feet long and 97 feet wide, in the bed of a quarry which is still being operated. It lies within three hundred feet of Pond I. It is surrounded on all sides by a desert of bare rock or finely crushed stone for distances of seventy-five feet to a hundred yards or more. By reason of this wide belt of bare territory this pond is probably more isolated than are the two just described.

Stations 1 and 2 of Pond III.

The water was between four and five feet deep, except for a small area where it was ten feet deep. This is about eighteen inches less than the depth sometimes attained. There was very little vegetation; two small willow trees and some rushes growing in a shallow stretch along one side. In the center of the pond there were thirty-two lily pads. None of these was seen before the summer of 1917. Except for such few traces of larger vegetation the pond presented a bleak appearance. Stones in the water were well coated with algæ, even at a depth of several feet. The bottom was covered with two to three inches of black silt composed of dust from the quarry and an admixture of decayed organic material from the pond itself.

The water was so turbid that the transparency disk disappeared two inches below the surface. This unusually low degree of transparency was due in large part to the great quantity of plankton, particularly the phytoplankton, which was so abundant as to make the water green. Tests failed to show any carbon dioxide either at the surface or at the bottom. The temperature of the water was 29° C. just below the surface; midway to the bottom and on the bottom it was 28° C.

STATION 1. The side of the pond at this point was a face of solid rock similar to that shown in the left background of the photograph on page 450. The water was two feet deep. A miscellaneous assortment of stones was scattered over the bottom. The forms found here were on these stones. A list of them is given in Table 12.

TABLE 12.

Group / Insecta	Species	Counts	Remarks
Coleoptera	Hydroporus concinnus	2	Area 12″ x 18″. In algæ on rock.
Diptera Larvæ	Chironomus dux	50	Area 5 x 2 feet.
	Chironomus modestus	.	
	Chironomus sp	12	Surface area stones 4″ x 4″.
Ephemeridæ Nymphs	Heptagenia variabilis	5	Area 4″ x 3″.
Tricoptera Larvæ	Polycentropus sp	9	Surface area stones 4″ x 4″.
Mollusca	Physa heterostropha	6	Area 12″ x 18″.
	Eggs of Physa, masses	4	
Annelida	Glossiphonia nepheloidea	1	Entire station.
Coelenterata	Hydra fusca	..	

The *Physæ* were present down to the depth of a foot. The beetle *Hydroporus* was taken in the algæ along the water's edge. The numbers given for the various individuals were taken at random from several counts and represent average conditions. The numbers for the may-fly nymphs and the chironomid larvæ indicate the average abundance of these species, on stones of the size indicated, over the entire pond.

STATION 2. A pile of stones came to the surface at this point. The situation is shown in the left half of the photograph on page 450 just below the small bush. The animals found are given in Table 13. Except for the beetles they were all taken below the surface of the water on stones. The beetles were running over the exposed portion of the stone pile near the water's edge.

TABLE 13.

Group	Species	Counts	Remarks
Coleoptera	Hydroporus concinnus Agabus disintegratus	1 2	Area 12″ x 18″.
Diptera Larvæ	Chironomus dux Chironomus sp Psychodid	15 ..	Area 4″ x 3″.
Ephemeridæ Nymphs	Blasturus sp Heptagenia variabilis	3 4	Area 4″ x 5″.
Tricoptera	Polycentropus sp	6	Area 4″ x 3″.
Mollusca	Physa heterostropha Egg masses of Physa	4 10	Area 12″ x 18″.
Annelida	Glossiphonia nepheloidea	2	

STATION 3. Along the west side of the pond a pile of stones projected above the surface of the water. Among them there was a group of reeds. The conditions are shown on page 453. The animals named in Table 14 were taken in four to five inches of water from stones about the roots of the reeds.

TABLE 14.

Group	Species	Counts	Remarks
Diptera Larvæ	Chironomus sp Chironomus modestus	30 40	Area 7 x 4 feet. Area 2 x 4 feet.
Crustacea	Cypris sp Asellus attenuatus	.. ..	
Mollusca	Physa heterostropha Planorbis parvus	3 2	Area 12 x 18 inches.
Annelida	Glossiphonia stagnalis	2	
Vertebrata	Tadpole (Rana)	..	

STATION 4. This covers the central area and also includes the plankton and the free swimming forms of the pond as a whole. As mentioned previously several lilies had become established in the center of the pond. Their roots were imbedded in three inches of silty mud. A list of the species is arranged in Table 15, page 454.

The fish were, of course, artificially introduced. The turbidity of the water made it impossible to see them and thus gain even an approximate idea of how many there were. Their numbers were probably not great, due both to the size of the pond and to the fact that the youngsters of the neighborhood caught them frequently. The general appearance of the pond did not leave the impression that it was a particularly suitable environment for fishes. However, so far as food was concerned there could have been little difficulty in view of the enormous amount

Station 3 of Pond III.

of insect life and the great quantity of algæ. The presence of young catfish and of hatching eggs showed that this species was able to propagate. There was no evidence of breeding on the part of the sunfish.

The stomachs of two sunfish and a catfish were examined. Their contents was as follows:

1. Eupomotis gibbosus	Ephemerid nymphs, 3. Chironomus larvæ, 2.
2. Ameiurus natalia	Shell of Physa. Ephemerid nymphs, 2. Algæ.
3. Eupomotis gibbosus	Ephemerid nymphs, 6. Algæ, considerable.

TABLE 15.

Group	Species	Lilly Leaves	Sediment	Nekton	Plankton	Surface of Water	Remarks
Hemiptera	Gerris conformis	..	..	..	..	x	Only one seen.
Entomostracan Crustacea	Diaptomus sp	..	..	..	x	..	
	Cyclops ater	..	..	..	x	..	
	Bosmina longirostris	..	..	..	x	..	
	Nauplius (cyclops)	..	..	..	x	..	
Rotifera	Cathypera luna	..	..	..	x	..	
	Triarthra longiseta	..	..	..	x	..	
	Rotifer neptunis	..	..	..	x	..	
Nemathelminthes	Nematode	..	x	..	..	..	
Mollusca	Ancylus shimeki	x	..	..	..	..	
Protozoa	Pleodorina sp	..	..	..	x	..	
	Ceratium longicorne	..	..	..	x	..	
	Chilomonas sp	..	..	..	x	..	
	Euglena viridis	..	..	..	x	..	
Vertebrata	Lepomis cyanellus	..	..	x	..	..	
	Ameiurus natalis	..	..	x	..	..	
	Eggs of catfish	..	..	..	..	..	
Algæ	Merismopaedia	..	..	..	x	..	
	Pediastrum	..	..	..	x	..	
	Scenedesmus	..	..	..	x	..	
Total number of species		1	1	2	14	1	

Plankton. The plankton catch was taken within a foot of the surface. The quantitative results are given in Table 16. It will be seen that the blue-green algæ comprised by far the greatest part of the catch. This abundance is not a casual occurrence. Sample towings taken in other years offer ample evidence of similarly large quantities of algæ. The figures given in the table have reference to the number of algal filaments.

TABLE 16.

Plankton Quantitative Results.

Species	Number in 100 Liters	Per Cent of Total
Blue-green algæ	685,250	80.
Pleodorina	67,000	7.9
Nauplius	55,800	6.5
Pediastrum	17,850	2.1
Ceratium	11,160	1.3
Rotifera	10.892	1.2

Discussion. All of the animals inhabiting the pond and the types of environment in which each was found are given in Table 17, page 455. About one-third of the total number of species were insects. The other inhabitants were rather evenly distributed through five groups. In these groups plankton and pelagic types were by far the most numerous.

TABLE 17.

SUMMARY OF SPECIES IN TEN YEAR POND.

Group	Species	Station 1	Station 2	Station 3	Station 4
Coleoptera	Hydroporus concinnus	x	x	..	..
	Agabus disintegratus	..	x	..	..
Diptera larvæ	Chironomus dux	x	x	..	..
	Chironomus modestus	x	..	x	..
	Psychodid	..	x	..	..
Ephemeridæ nymphs	Heptagenia variabilis	x	x	..	..
	Blasturus sp	..	x	..	..
Hemiptera	Gerris conformis	..	..	..	x
Tricoptera	Polycentropus sp	x	x	..	..
Entomostracan crustacea	Cypris sp	..	..	x	..
	Asellus attenuatus	..	..	x	..
	Diaptomus sp	..	..	..	x
	Cyclops ater	..	..	..	x
	Bosmina longirostris	..	..	..	x
	Nauplius (cyclops)	..	..	..	x
Mollusca	Physa heterostropha	x	x	x	..
	Planorbis parvus	..	..	x	..
	Ancylus shimeki	..	..	..	x
Annelida	Glossiphonia stagnalis	..	..	x	..
	Glossiphonia nepheloidea	x	x	..	..
Rotifera	Cathypera luna	..	..	..	x
	Triarthra longiseta	..	..	..	x
	Rotifera neptunis	..	..	..	x
Nemathelminthes	Nematode	..	..	..	x
Coelenterata	Hydra fusca	x	..	..	..
Protozoa	Pleodorina sp	..	..	..	x
	Ceratium longicorne	..	..	..	x
	Chilomonas sp	..	..	..	x
	Euglena viridis	..	..	..	x
Vertebrata	Lepomis cyanellus	..	..	..	x
	Ameiurus natalis	..	..	..	x
	Tadpole (Rana)	..	..	x	..
Algæ	Merismopedia	..	..	..	x
	Pediastrum	..	..	..	x
	Scenedesmus	..	..	..	x
Total number of species		8	9	7	19

The only forms which were well represented in point of numbers were the midges and the mayflies. Two factors are probably mainly responsible for the scarcity of other species. The fishes are the factor operating to reduce the pelagic insect population, whereas the almost total absence of vegetation and debris may be held accountable for the poor representation in other groups.

A comparative summary of counts, exclusive of the plankton, made at the various stations is arranged in Table 18, below. This shows a remarkably uniform density of population for a given species wherever it occurred, a condition which was most clearly and completely shown for the whole pond by one of the chironomid larvæ. The actual numbers given for Station 3 are twice as great as for either of the other two but it is to be noted

TABLE 18.

Summary of Counts.

	Station		
	1	2	3
Chironomus dux and modestus	5 x 12 50		
Chironomus sp.	4 x 4 12	4 x 3 15	7 x 4 30
Chironomus sp.			2 x 4 40
Heptagenia variabilis	4 x 3 5	4 x 5 4	
Blasturus sp.		4 x 5 3	
Hydroporus concinnus	12 x 18 2	12 x 18 1	
Agabus distintegratus	·	12 x 18 2	
Polycentropus sp.	4 x 4 9	4 x 3 6	
Glossiphonia nepheloidea	Station 1	12 x 18 2	
Glossiphonia			Station 2
Physa heterostropha	12 x 18 6	12 x 18 ·4	12 x 18 3
Egg masses of Physa	18 x 18 4	12 x 18 10	
Planorbis parvus			12 x 18 2

that the area is also doubled. In the case of other insects, counts were obtained from two stations at most. The distribution of these was not quite as uniform as in the case of the chironomids. The leeches and snails were present in about the same numbers wherever they occurred but with nothing like the density of population shown by the larval insects. The pond as a whole was thus clearly more suited to the larval insects inhabiting it than to the other macroscopic forms. As was to be expected the plankton conditions were uniform throughout. I have no actual data on the fish distribution but I assume that the chief limiting factor would be extreme variation in the depth of the water. Apparently, then, the pond offered an almost equally suitable environment wherever a given species was found.

These counts give us data not only on the uniformity of distribution, but they also furnish some conception of the actual numbers which a pond of this comparatively small size can maintain. Assuming that the entire bottom was as thickly populated as the sample counts indicate the total number of the one species of chironomid larvæ would have been 2,444,400 and of the *Heptagenia* nymphs, 814,800. It is true that the muck covering much of the bottom offered an unsuitable habitat and was therefore, not as thickly populated but the above calculation is based on a surface in a single dimension only and when we consider that several thousand stones are equally populated on all sides the calculation is probably not far from the actual condition.

FIFTEEN YEAR POND.

Pond IV.

The fifteen-year pond is on Kelley's Island, Lake Erie, five miles off the Marblehead Peninsula. The entire island is a solid mass of rock covered by a thin layer of soil. The pond fills a shallow crescentic excavation in the rock, 100 by 150 feet in surface area. Along one side there is a public road, on another a lawn, and elsewhere a pasture. A portion of the pond is shown on page 458.

The depth of the water varied from eighteen inches to three feet with an indicated fluctuation of six inches. At each end of the pond, soil had slipped down to the water's edge and on this some willow bushes had become established. Here there was a foot or more of muck near shore which rapidly became less deep farther out. Mixed in with it was a miscellaneous collection of sticks, leaves and other debris. The surface of the water at one end was covered for several feet from shore with a thick mat of filamentous algæ. Narrow strips of this mat extended some distance down each side. The shore was chiefly bare rock. Here and there a small bunch of willow shoots had obtained a foothold. The crevices and narrow ledges awash with the water were covered with algæ. Beyond the area of muck the amount of material on the bottom was at most three inches deep. In some places it was not more than an inch deep or barely that. This material consisted of dust from the road and of a considerable amount of decayed organic substance, chiefly algal.

Part of the Fifteen Year Pond.

The temperature of the water was 29° C. The water was kept more or less constantly stirred up by cows which frequently stood in one end of the pond. As a result it was so turbid that the transparency disk disappeared at six inches. The turbidity would have been great even had the cattle not been present by reason of the great abundance of the plankton algæ. These colored the water green. The cattle also made the water so foul as to give it a disagreeable odor. This was the only one of the ponds in such a condition.

The character of the pond was such that it did not seem necessary to divide it into stations. All the forms have been placed in a single table, Table 19, page 459. To the right, opposite each species there is indicated in a word, their relative abundance.

All of the species in this pond were also to be found in ponds on the mainland. There were no peculiarly island types. For most of the inhabitants in isolated ponds such as these in this series a few miles of water are probably no more of a barrier than as many miles of land. In fact it may be less of a barrier since it is an inhabitable medium.

TABLE 19.

Group	Species	Surface of Water	Muddy Shore	Algæ	Muck on Bottom	Nekton	Submerged Stones and Sticks	Remarks
Coleoptera adults	Gyrinus aquiris	x	..	..	..	x	..	Few
	Loxandrus sp	..	x	..	..	..	..	Numerous
	Hydroporus concinnus	..	x	..	..	..	..	Common
	Dytiscid (larva)	..	..	x	..	..	..	Scarce
Diptera larvæ	Chironomus sp	..	..	..	x	..	x	Numerous
	Larva, unidentified	..	..	..	x	..	x	Scarce
Ephemeridæ	Heptagenia variabilis	..	..	..	..	..	x	Few
Hemiptera	Gerris conformis	x	..	..	..	..	..	Few
	Notonecta insulata	x	..	..	..	x	..	Scarce
	Corisa sp	x	..	..	..	x	..	Scarce
Arachnida	Dolomedes sexapunctata	..	..	..	..	x	..	Scarce
Entomostracan Crustacea	Potamocypris sp	x	..	..	..	x	..	See Table 20
	Cypris inequivalva	..	..	..	..	x	..	
	Cypris sp	..	..	..	..	x	..	
	Diaptomus sp	..	..	..	..	x	..	
Mollusca	Lymnaea palustris	..	x	x	..	..	..	Common on mud
	Physa heterostropha	..	x	x	..	..	..	Numerous on mud
Annelida	Lumbriculus sp	..	..	x	..	..	..	Few
	Glossiphonia nepheloidea	..	..	..	..	..	x	Few
Rotifera	Rotifera neptunis	..	..	..	..	x	..	See Table 20
	Brachionus sp	..	..	..	..	x	..	
Protozoa	Ceratium longicorne	..	..	..	..	x	..	
	Arcella vulgaris	..	..	..	..	x	..	
Total number of species		5	4	4	2	12	4	

The catfishes were the only inhabitants that would have had to be introduced by human agency. The turtles were also probably introduced in this way but there is a possibility of their having migrated from the lake. Assuming that other fishes had been thrown into the pond, on which point I have no data, catfish were apparently the only fish that contrived to survive. Their young were numerous. Two physical factors probably operated against the survival of other fishes: (a) the quantity of silt, more or less constantly kept suspended in the water by the cattle; and (b) the foulness of the water also due to the cattle.

In connection with the absence of surface feeding fishes it is interesting to observe that the surface and pelagic insects such as *Notonecta*, *Corisa* and *Gyrinus* were present.

From the quantitative plankton table, Table 20, it will be seen that the phytoplankton made up by far the greater part of the entire plankton. The quantity of zooplankton was not large. All members of the zooplankton composed an approximately equal portion of it. Although *Potamocypris* was the least abundant of the plankton species, it was present in swarms that covered large patches of the surface. This abundance was merely a temporary matter since it is a species that is usually most in evidence during a few weeks only.

TABLE 20.

Plankton Quantitative Results.

Species	Number in 100 Liters	Per Cent. of Total
Closterium	535,750	94.
Potamocypris	5,000	.878
Cypris inequivalva	5,890	1.03
Cypris sp	6,250	1.09
Rotifera	5,750	1
Ceratium longicorne	5,250	09
Arcella vulgaris	5,375	.09

THIRTY YEAR POND.

Pond V.

In the grounds of the Soldiers' Home at Sandusky there is a group of three ponds supplied with water by a small stream from nearby springs. The ponds are at different levels and water passes successively from one to the other when there is enough of it to cause an overflow. At times the lower pond overflows and, by means of a ditch, connects with a creek about one-third of a mile distant. In the source of the water and in the occasional connection with the creek these ponds differ from the others included in this survey. These conditions may suggest that Pond V is not in a class with the others. The differences are not so vital, however, as they appear. The supplying stream, because of its own isolation and short extent, can have had little influence in introducing forms which would not otherwise have reached the ponds. The connection with the creek has been such an intermittent occurrence that any possible migration along this route must have been precarious.

Each of the three ponds was examined but attention was centered on the lower one. If there has been faunal contamination, so to speak, from the creek this pond would have been most effected, although once a form had migrated along the ditch to this point it could have gone on to the two upper ponds. The natural sequence of physical changes has apparently been least interfered with by man in the lower pond. Except for some masonry at one end to build a bridge and at the other to make an outlet, the conditions have taken a natural course.

A portion of the Thirty Year Pond.

The pond has an area of eighty by eighty-five feet. A portion of it is shown above. Its edges were still littered with the fragments of stone common about a quarry. Above these was a lawn and trees. The water was two to four feet deep, although this depth may vary as much as a foot from year to year. I have never seen it overflowing into the ditch. Its temperature was 29° C. The surface of the water has usually been well covered with *Lemna*. Beneath this, and distributed rather generally, there were filamentous algæ. From four inches to a foot of rich, black sediment, largely composed of decayed vegetation, covered the bottom. In this at several spots the pond lily, *Castalia tuberosa*, had taken root. Sticks and small branches were scattered about promiscuously. Along the edges there was a miscellaneous litter of leaves, sticks and

TABLE 21.

Group	Species	Surface of Water	Littoral Rocks	Surface of Muck	Algæ	Lilly Roots	Lilly Leaves & Stalks	Muck	Stones in Water	Plankton	Nekton	Remarks
Coleoptera adults	Hydroporus concinnus	..	..	..	x	..	..	..	..	..	..	Common
	Laccophilus maculosus	x	..	..	..	..	..	..	..	..	..	Few
	Agabus disintegratus	..	1	..	..	..	..	..	..	..	..	
	Philhydrus ochraceus	..	..	..	..	..	x	..	..	..	..	Few
	Loxandrus sp	..	..	2	..	..	..	..	..	..	..	
	Cnemidotus edentulus	..	..	..	x	..	..	..	..	..	..	Few
	Gyrinus aquiris	x	..	..	..	..	..	..	..	..	..	Scarce
	Stenus annularis	..	..	..	..	3	..	..	..	..	..	
	Dytiscid, larva	..	..	..	x	..	..	..	..	..	..	Few
Diptera larvæ	Tabanus sp	..	..	..	..	x	..	..	..	..	..	Scarce
	Chironomus sp	..	..	..	x	..	..	..	..	..	..	Few
	Chironomus sp	..	35	..	..	..	..	..	..	..	..	
	Metriocnemus sp	..	10	..	..	..	..	..	..	..	..	
	Ceratopogon sp	..	..	..	..	x	..	..	..	..	..	Few
Odonata nymphs	Sympetrum sp	..	..	..	2	..	..	..	..	..	..	
	Pachydiplax longipennis	..	..	..	..	..	1	..	..	..	..	
	Tetragoneuria cynosura	..	..	1	..	..	..	..	..	..	..	
	Anomalagrion sp	..	..	..	..	..	..	..	5	..	..	
Ephemeridæ nymphs	Caenis allecta	..	x	..	x	..	..	..	29	..	..	
	Heptagenia variabilis	..	15	..	..	..	..	..	x	..	..	
Hemiptera	Gerris conformis	x	..	..	..	..	..	..	..	..	..	Scarce
	Zaitha fluminea	..	3	..	..	..	..	..	..	..	..	
Crustacea	Asellus attenuatus	..	x	x	x	..	..	..	12	..	..	
	Cambarus virilis	..	3	..	..	..	..	..	..	..	..	
	Cypris inequivalva	..	..	..	..	..	..	..	..	x	..	
	Bosmina longirostris	..	..	..	..	..	..	..	..	x	..	
	Scapholebris sp	..	..	..	..	..	..	..	..	x	..	
	Ophryoxus sp	..	..	..	..	..	..	..	..	x	..	
	Ceriodaphnia sp	..	..	..	..	..	..	..	..	x	..	
	Potamocypris sp	..	..	..	..	..	..	..	..	x	..	
	Chydorus sphaericus	..	..	..	..	..	..	..	..	x	..	
	Nauplius	..	..	..	..	..	..	..	..	x	..	
Mollusca	Planorbis parvus	..	1	..	..	..	..	..	..	..	..	
	Physa heterostropha	..	43	..	x	..	..	..	..	..	..	
	Lymnaea humilis	..	..	x	..	..	..	..	..	..	..	
	Limax maximus	..	x	..	..	..	..	..	..	..	..	
	Pallifera sp	..	x	..	..	..	..	..	..	..	..	
Annelida	Glossiphonia stagnalis	..	..	..	..	..	..	..	4	..	..	
	Sparganophilus eiseni	..	..	..	..	..	..	x	..	..	..	Few
Rotifera	Brachionus bakeri	..	..	..	..	..	..	..	..	x	..	
	Aneuria cochlearis	..	..	..	..	..	..	..	..	..	..	
	var macrocantha	..	..	..	..	..	..	..	..	x	..	Numerous
	Aneuria cochlearis	..	..	..	..	..	..	..	..	x	..	
Plathelminthes	Planaria maculata	..	x	..	x	..	x	x	100	..	..	4″ x 5″
Protozoa	Difflugia corona	..	..	..	..	..	..	..	..	x	..	
	Ceratium longicorne	..	..	..	..	..	..	..	..	x	..	
Vertebrata	Lepomis pallidus	..	..	..	..	..	..	..	..	..	x	Few
	Ameiurus sp	..	..	..	..	..	..	..	..	..	x	Few
	Cyprinus carpio	..	..	..	..	..	..	..	..	..	x	Few
	Chrysemis marginata	..	..	..	..	..	..	..	..	..	x	Few
	Tadpole (Rana)	..	..	..	..	..	..	..	..	..	x	Few
Total number of species		3	13	4	9	3	3	2	6	13	5	

weeds. The physical conditions were everywhere so nearly uniform and the distribution of the inhabitants was so general that the pond has been treated as a unit.

It will be seen by a glance at Table 21, page 462, that most of the inhabitants, probably all of them except the fishes, are such as could have entered by natural means even though there had not been the partial connection with the creek. This connection may have made it easier for the crayfish (*Cambarus*), the snails (*Planorbis* and *Physa*), the leech (*Glossiphonia*), the annelid (*Sparganophilus*) and the planaria to have entered but all of these are to be found in entirely isolated bodies of water so that there is really no inhabitant, aside from the fishes, which would probably not have been present under isolated conditions.

The rich representation of insects is the outstanding feature, but the animal characteristic of the pond is a flatworm, *Planaria maculata*. It was teeming over every submerged solid object. I have never seen planaria so abundant anywhere. This condition was constant for the three summers over which my observations extended. The worms were about as numerous in the middle pond but they were decidedly less so in the upper one.

In connection with the insects it should be mentioned that while a number of species are represented, the number of individuals in all but a few species is small. The presence of such a variety of shore frequenting coleoptera is to be accounted for by the debris about the edges of the pond which afforded a suitable environment. Apparently the conditions were not especially suitable for breeding since the absence of coleopterous larvæ was markedly noticeable. The species of insects which were represented by numerous individuals all had larval stages in the pond also.

The isopod, *Asellus attenuatus*, was common everywhere, but was not noticeably abundant. The same can be said regarding the may-fly nymphs. *Glossiphonia* was more frequently seen on the lower stones nearest the muck.

The catfish and the carp are included on the authority of persons living near the pond. I did not see either species myself. The muddy nature of the bottom and the generally congested conditions appeared to offer a more favorable environment for either of these fishes than for the sunfish. The presence of surface feeding fishes is reflected by the almost total absence of surface and pelagic insects.

TABLE 22.
Plankton Quantitative Results.

Species	Number in 100 Liters	Per Cent. of Total
Bosmina longirostris..........	6,300	36.4
Scapholebris sp..............	1,250	7.2
Ophryoxus sp................	2,250	13.
Ceriodaphnia sp..............	2,250	13.
Potamocypris sp..............	1,000	5.7
Nauplius.....................	2,250	13.
Brachionus bakeri............	2,000	11.
Ceratium.....................	Trace	
Arcella......................	Few	

The plankton in this pond was predominantly zooplankton. The quantitative results are given in Table 22. *Bosmina longirostris* was the species present in the greatest abundance. All the others were far less numerous.

GENERAL DISCUSSION OF THE SERIES.

Physical Features.

A summary of the main physical features of the five ponds has been arranged in Table 23, page 465. It will be seen that there is a great difference in size between the largest and the smallest; the two younger ponds are from five to ten times larger than the three older ones. The latter are very nearly of a size. In harmony with the size differences there is a corresponding difference in temperatures; the larger bodies of water are a degree cooler than the smaller.

In a series of ponds such as we have here it is possible to gain some idea of the rate at which sediment accumulates. The amount of sediment which collects on the bottom of a pond as it increases with age is a matter of far reaching importance because of its influence on vegetation and on animal inhabitants. The rate at which this accumulation takes place is of value in determining the age of ponds whose past history is unknown.

The first of the two amounts indicating the depth of sediment for each of the ponds in Table 23 is the more accurate record of actual accumulation. The maximum depth of sediment in the one year and the five year ponds was in an area where the suction of a pump used in keeping the quarries dry had accumulated considerable material from over a wide region. In all of the ponds there was an original layer of quarry dust which was from one-eighth to one-fourth inch thick. It is therefore safe to assume that the amount of organic material from the pond itself and of dust or other material from without which had accumulated on the bottom of the one year and five year ponds is negligible. A thick mat of algæ in the one year pond was furnishing a good source for such accumulations. The great amount of plankton in this pond during its second summer would also add to it.

TABLE 23.

Pond	Surface Area, sq. ft.	Depth, feet	Centigrade Temperature*	Transparency	Sediment		Vegetation	Environment
					Depth, Inches	Nature		
One year	(150x500) 75,000	.... 1½–8	(26°) 28°	As depth	.... ⅛–4	Silt (muck)	Algæ (chara)	Bare quarry bed. Cultivated fields.
Five year	(350x400) 140,000	.... ¼–13¾	(21°) 28°	.... 9′ 3½″	.... ¼–4	Silt & muck	Algæ chara	Bare to sparsely covered quarry bed; cultivated fields.
Ten year	(97x140) 13,580	.... 1½–10	(28°) 29°	.... 10″	 4	Black silty mud	Algæ Lilies Rushes	Bare quarry bed. Cultivated fields
Fifteen year	(100x150) 15,000	.... 1½–3	(29°) 29°	.... 6″	 3–12	organic silt mud	.... Algæ	Pasture, lawn, road.
Thirty year	(85x80) 6,800	 2–4	(28½°) 29°	.... 2′ 6″	 4–12	.... muck	Lilies Algæ	Lawn and shade trees.

*Temperature in parenthesis was taken at the bottom.

The rich plankton of the ten year pond must form a considerable layer of sediment each year. Added to this is undoubtedly quite an amount of material from the surrounding quarry the floor of which was quite dusty. The twelve inches of material recorded for the fifteen year pond was along one end where soil from above had slipped over the edges. Thick mats of algæ were evidently the chief source of organic deposit. In the thirty year pond the algal deposits were augmented by leaves from surrounding trees. The normal accumulation of this pond was increased by material washed down from the two ponds above it.

This series also furnish some data with regard to the rate at which rooted vegetation can become established on a substratum originally of rock. The five year pond had reached the point where it could support such vegetation in the form of

Chara. This is excluding from consideration the *Chara* in the year old pond since it became established in a pool antidating the present pond. Even for the *Chara* in the five year pond the substratum was artificially provided through the action of a pump. It should be noted in this connection that vegetation had already gained a footing about the five year pond, on the portion of the quarry bed not covered with water. It is therefore probable that the pond would have been able to support emergent vegetation if the water had not been so deep. As it is we find emergent vegetation, lilies and reeds, first appearing in the ten year pond. The irregularities of the situation are apparent, however, in the fact that the fifteen year pond had no rooted vegetation. This should be attributed to the cattle or to some other cause not connected with the substratum since parts of this pond offer a better foothold for vegetation than the ten year pond.

In considering the physical changes which have occurred it should be kept in mind that an important factor is the relative situation of the ponds with regard to sources of extraneous material. Ponds which are entirely surrounded by the bare bed of a quarry are not nearly so likely to be filled nor to undergo alterations along their shores as are those more closely surrounded by fields or trees. The ten year pond, for example, is in most physical features no farther advanced than the one a year old. The three younger ponds are so situated that by the time they attain the present age of the two older ones they will not have reached the present physical condition of the older ponds. The evidence from this series, then, is that the physical transformation which occurs in a rock bottom pond is not in proportion to age, at least during the first thirty years. However, this change, whatever its rate, causes such a pond to approach the condition of one established on a bottom of earth.

The Fauna.

The distribution of the various species through the five ponds of this series is summarized in Table 24, page 471. One of the interesting features brought out by the summary is the great number of species which are found in only one pond. Out of a total of 112 species for all ponds 65 species were present in but one pond, twenty-eight were in two, nine species were in three of them, four were present in four ponds and five species, also, were found in all of the ponds.

The cosmopolitan species were a chironomus larva, a water strider (*Gerris*), a may-fly (*Heptagenia*), a protozoan (*Ceratium*) and the snail *Physa*. Most of these are species which are to be found in almost any body of fresh water. In the distribution of the forms inhabiting but one pond we find them rather evenly scattered among all the ponds except the one fifteen years old. And so, too, with those present in two, three and four ponds respectively, there is an approximately even distribution of them through the series.

Practically all of these species are commonly found over a wide area. Their manner of distribution in these ponds, therefore, clearly shows that there may be great regional uniformity in the distribution of a species and, at the same time a local absence of uniformity even in habitats which, superficially at least, are apparently similar. The data given in connection with the respective ponds is sufficient to show that this condition can be traced in large part to the environment presented by each pond. To determine all of the factors in each case with any degree of completeness would take a much more detailed study extending over a greater period of time than I have been able to give the subject.

Regarding succession, it is hard to draw general conclusions because, over and above the natural sequence of environmental changes which is to be expected, each pond has a peculiar set of conditions which complicates the problem. However, a certain degree of faunal development is evident.

In the year old pond the following groups had become established: *Coleoptera* (larvæ and adults), *Diptera* (larvæ), *Ephemeridæ* (nymphs), *Hemiptera* (nymphs and adults), *Tricoptera* (larvæ), *Arachnida*, *Entomostraca*, *Mollusca* (snails), *Rotifera*, *Hirudinea*, *Protozoa*, and, if we exclude *Chara* as antidating the pond, filamentous algæ. The prominent faunal features in this pond are the great abundance of insects both in species and in individuals of certain species; also the fact that there were no vertebrates and, with two exceptions (*Arachnida* and *Mollusca*) fewer species of any other group than in any of the other ponds.

Insects composed twenty-seven out of forty-three species. There are both environmental and morphological reasons for this. Wings and flying as a means of locomotion enable insects to reach an isolated body of water before other forms which might inhabit it but which are unable to reach it because of intervening obstacles. Further, once having reached it, adult insects can be semi-independent of a pond as a source of food. They can frequent it, even lay their eggs, and thus start an entirely aquatic fauna, and yet go elsewhere for their food. The absence of fishes, predaceous enemies of insects, is also an important factor. In point of numbers the aquatic insects *Notonecta*, *Corisa* and *Gyrinus* were by far the most abundant. Freedom from predaceous enemies permitted them to live and increase without hindrance. The influence of such enemies is clearly shown in a comparison of the one year with the five and the ten year pond. Both of the latter are well populated with fishes and in both, the strictly aquatic adult insects are entirely absent from the area which the fish can reach. The ten year pond is within a hundred yards of the one a year old and the five year pond is over six miles away. It is thus not a matter of location. In the fifteen year pond, on the other hand, the fishes are bottom feeders and here surface insects again appear.

The insect situation existing in these ponds does not agree with results found by Shelford* in a series with sandy bottoms. He states that aquatic insects are not numerous in the younger ponds but that they increase in the older with an increase in the vegetation. It should be noted, however, that in the youngest pond of his series there were ten species of fishes whereas in the oldest pond there were only four and these were not especially insectivorous.

The five year pond is primarily notable for the fact that fishes were firmly established. They were the dominating members of the fauna. Odonata nymphs had also become established. *Hydra* was observed here first and so, too, were nematoda and chætopod annelids. Over most of the pond there was no suitable environment for littoral animals. That the absence of such forms was not a matter of distribution is to be seen from the fact that at least some of these were present in pools at one side of the pond.

In the ten year pond emergent vegetation, lilies and reeds, had gained a footing. Along with this appeared a new type of mollusc, namely *Ancylus*. So far as my observations went the vegetation could not be correlated with the presence of any other species. The most abundant members of the fauna were chironomid larva and ephemerid nymphs.

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* Animal Communities of Temperate North America.

The ten year and the one year ponds make an interesting comparison because of the fact that they lie side by side and both offer a bleak habitat. Their chief physical difference was in size. Faunally they differed most markedly in respect of their hemiptera, larval beetles, diptera and ephemeridæ. The two species of hemiptera so abundant in the one year pond were not in the ten year pond. The species of diptera and ephemeridæ were not the same in the two ponds. There were no larval beetles in the ten year pond. The absence of these is to be correlated with the greatly reduced number of adult species represented, as compared with the one year pond. In point of numbers the gyrinid and the dytiscid larvæ composed the larger part of all coleopterous larvæ in the one year pond. Adults of neither of these groups were in the ten year pond.

Several factors are probably responsible for the absence of the beetles from the ten year pond. The presence of fishes undoubtedly plays a large part. It is also to be noted that some of the species in the one year pond apparently prefer clear water. For example, Blatchley* states that *Philhydrus* rises to the surface when the water becomes turbid. The water in the ten year pond was decidedly turbid and this may therefore be a factor. Furthermore, there was little in the way of debris about the edges of this pond to attract the shore inhabiting species.

Two of the three species of ephemerid nymphs in the one year pond were not in any of the others. Their adults also were not numerous in the region. *Heptagenia*, the form in the ten year pond, was the most abundant member of this group in the region. Its chances for general distribution as a nymph were therefore greater and, as matter of fact, it was one of the types found in all of the ponds. Possibly the regional scarcity of the two species in the one year pond was a factor responsible for their absence from most members of the series.

In the fifteen year pond there were certain abnormal conditions which perhaps made it hardly a fair test of pond development at this age. It was the first pond offering conditions suitable for microdrilus oligocheta. This is said not merely because *Lumbriculus* was present but also because under the conditions it would have been surprising to have found them in the younger ponds. Turtles were seen for the first time and catfish also found a suitable environment.

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*Coleoptera of Indiana.

This pond had the least number of species represented in its population. In view of its age and also of the fact that it presented a less barren environment than the three younger ponds, one could expect to find it inhabited with a greater variety of species. The island situation is one of the first reasons to suggest itself in explanation of this state of affairs. An examination of Table 24 will show that for most groups this pond compared favorably with the others in the number of species represented. Its non-flying population such as annelida, mollusca, etc., was about equal to that of the other ponds. In beetles it bore comparison with the five and the ten year ponds. The greatest loss in species came in the flying groups diptera, ephemeridæ and tricoptera. Isolation is hardly a satisfactory explanation for loss in representation among these species. It seems more probable that the condition of the water rendered the pond uninhabitable for larval members of some of the groups found in the other ponds.

The thirty year pond presented several new species. Strange as it may seem *Planaria* was found here for the first time. It was by far the most abundant member of the association. Crayfish also appeared here first and so did slugs and an annelid, *Sparganophilus*. This worm is to be found about the roots of aquatic plants in marshes and older ponds, although I have found it also along the pebbly and stony beach of a partly protected bay on Lake Erie.

The slugs, *Limax* and *Pallifera*, were both in moist situations under debris along the water's edge. The moisture and shade afforded them by the grass and trees in the surroundings would enable them to reach this situation without undue exposure to dry conditions. The only other pond with approximately similar surroundings was the one fifteen years old. All the others were bordered by a greater or less expanse of bare rock which presented desert conditions to any animal that would have attempted to migrate across it by crawling or creeping. In this respect the one, five and ten year ponds had an additional degree of isolation which undoubtedly prevented certain types of animals from reaching them. Until this bare expanse of rock is covered by vegetation it will continue to act as a barrier and thus aid in keeping the associations of the ponds in an ecologically younger condition.

The thirty year pond and the one a year old had almost the same number of insect species, but it will be noticed that, whereas in the youngest pond insects were abundant in both species and individuals, in the oldest pond they were abundant only in species. Furthermore, in the year old pond the species with the greatest number of individuals were represented either by pelagic adults or larval stages whereas in the thirty year pond most of the species are shore forms. Both ponds had the same number of species of adult beetles. Of the four present in the thirty year pond only, at least three are usually to be found among debris such as characterized the shore of this pond but not that of the younger one.

TABLE 24.

Group	Species	Ponds					
Insecta		1 Year	5 Year	10 Year	15 Year	30 Year	Total
	Hydroporus concinnus	x	..	x	x	x	4
	Hydroporus mixtus	x	..	..	..	..	1
	Tropisternus nimbatus	x	..	..	..	..	1
	Philhydrus ochraceus	x	..	..	..	x	2
Coleoptera	Dineutes assimilis	x	..	..	..	..	1
	Agabus disintegratus	x	x	x	..	x	4
adults	Coelambus laccophilinus	x	..	..	..	..	1
	Gyrinus aquiris	x	x	..	x	x	4
	Stenus sp	..	x	..	..	..	1
	Loxandrus sp	..	..	..	x	x	2
	Laccophilus maculosus	..	..	..	..	x	1
	Cnemidotus edentulus	..	..	..	..	x	1
	Stenus annularis	..	..	..	..	x	1
	Total adults	8	3	2	3	8	
	Peltodytes	..	x	..	..	..	1
	Dytiscidæ	x	..	..	x	x	3
Coleoptera	Gyrinidæ	x	..	..	..	..	1
	Hydrophilidæ	x	..	..	..	..	1
larvæ	Haliplidæ	x	..	..	..	..	1
	Lagriidæ	x	..	..	..	..	1
	Total larvæ	5	1	..	1	1	
	Tabanus sp	..	..	..	..	x	1
	Corethra sp	x	x	..	..	..	2
	Metriocnemus sp	x	..	..	..	x	2
Diptera	Tanypus sp	x	x	..	..	..	2
	Chironomus sp	x	x	x	x	x	5
larvæ	Chironomus dux	..	..	x	..	..	1
	Chironomus modestus	..	..	x	..	..	1
	Chironomus sp	..	x	..	..	x	2
	Psychodid	..	..	x	..	..	1
	Ceratopogon sp	..	..	..	..	x	1
	Total Diptera	4	4	4	1	5	
	Sympetrum sp	..	..	..	..	x	1
Odonata	Pachydiplax longipennis	..	x	..	..	x	2
	Tetragoneuria cynosura	..	x	..	..	x	2
nymphs	Anomalagrion sp	..	x	..	..	x	2
	Ischnura sp	..	x	..	..	..	1
	Total Odonata	..	4	..	..	4	

TABLE 24—(Continued).

Group	Species	Ponds 1 Year	5 Year	10 Year	15 Year	30 Year	Total
Ephemeridæ nymphs	Amelitus sp	x	..	..	..	..	1
	Caenis allecta	x	x	..	..	x	3
	Ephemerella excurcians	x	..	..	..	..	1
	Heptagenia variabilis	x	x	x	x	x	5
	Blasturus sp	..	..	x	..	..	1
	Total Ephemeridæ	4	2	2	1	2	
Hemiptera	Zaitha fluminea	..	..	..	..	x	1
	Gerris conformis	x	x	x	x	x	5
	Notonecta insulata	x	..	..	x	..	2
	Corisa	x	..	..	x	..	2
	Total Hemiptera	3	1	1	3	2	
Tricoptera larvæ	Leptocerid	x	..	..	..	..	1
	Hydropsyche sp	x	..	..	..	..	1
	Polycentropus	..	..	x	..	..	1
	Limnophilus	..	x	..	..	..	1
	Total Tricoptera	2	1	1	..	..	
Sialididæ	Sialid larva	x	..	..	..	..	1
Arachnida	Dolomedes sexapunctatus	..	..	..	x	..	1
	Pirata fibriculosa	x	..	..	..	..	1
	Limnochares aquaticus	x	..	..	..	..	1
	Total Arachnida	2	..	..	1	..	
Crustacea	Cypris inequivalva	..	..	..	x	x	2
	Cypris sp	x	x	x	x	..	4
	Asellus attenuatus	x	..	x	..	x	3
	Diaptomus sp	..	..	x	x	..	2
	Cyclops sp	x	..	x	..	..	2
	Cyclops ater	..	x	..	..	..	1
	Scapholebris sp	..	..	..	..	x	1
	Bosmina longirostris	..	x	x	..	x	3
	Ophryoxus sp	..	..	..	..	x	1
	Nauplius (cyclops)	x	x	x	..	x	4
	Cypridopsis vidua	..	x	..	..	..	1
	Daphnia sp	x	x	..	..	..	2
	Ceriodaphnia sp	..	..	..	..	x	1
	Chydorus sphaericus	..	x	..	..	x	2
	Potamocypris sp	..	..	..	x	x	2
	Cambarus virilis	..	..	..	..	x	1
	Total Crustacea	5	7	6	4	10	
Mollusca	Physa heterostropha	x	x	x	x	x	5
	Eggs of Physa	x	x	..	..	..	2
	Lymnaea humilis	x	..	..	..	x	2
	Ancylus shimeki	..	..	x	..	..	1
	Planorbis parvus	x	..	x	..	x	3
	Limax maximus	..	..	..	..	x	1
	Pallifera sp	..	..	..	..	x	1
	Lymnaea palustris	..	..	..	x	..	1
	Total Mollusca	4	2	3	2	5	
Annelida	Glossiphonia stagnalis	x	..	x	..	x	3
	Glossiphonia nepheloidea	..	..	x	x	..	2
	Sparganophilus eiseni	..	..	..	..	x	1
	Nais elinguis	..	x	..	..	..	1
	Lumbriculus sp	..	..	..	x	..	1
	Total Annelida	1	1	2	2	2	
Nemathelminthes	Nematode	..	x	x	..	..	2
Plathelminthes	Planaria	..	..	..	..	x	1
Coelenterata	Hydra fusca	..	x	x	..	..	2

TABLE 24—(Continued).

Group	Species	Ponds: 1 Year	5 Year	10 Year	15 Year	30 Year	Total
Rotifera	Distyla ludwigii	..	x	..	..	..	1
	Aneuria cochlearis	..	..	..	..	x	1
	Aneuria cochlearis var. macrocantha	..	..	..	..	x	1
	Brachionus bakeri	..	x	..	..	x	2
	Proales decipiens	..	x	..	..	..	1
	Cathypera luna	..	..	x	..	..	1
	Triartha longiseta	..	..	x	..	..	1
	Rotifera neptunis	..	..	x	..	..	1
	Total Rotifera	..	3	3	..	3	
Protozoa	Ceratium longicorne	x	x	x	x	x	5
	Dinobyron	x	..	..	..	..	1
	Chilomonas sp	..	..	x	..	..	1
	Euglena viridis	..	..	x	..	..	1
	Pleodorina	..	..	x	..	..	1
	Vorticella sp	..	x	..	..	..	1
	Difflugia corona	..	x	..	..	x	2
	Arcella vulgaris	x	x	..	x	..	3
	Total Protozoa	3	4	4	2	2	
Vertebrata	Cyprinus carpio	..	..	..	..	x	1
	Eupomotis gibbosus	..	x	x	..	..	2
	Lepomis pallidus	..	x	x	..	x	3
	Lepomis cyanellus	..	..	x	..	..	1
	Ameiurus natalis	..	..	x	x	..	2
	Ameiurus sp	..	..	..	..	x	1
	Perca flavescens	..	x	x	..	..	2
	Apomotis cyanellus	..	x	..	..	..	1
	Minnows	..	x	..	..	..	1
	Tadpole (Rana)	..	x	x	..	x	3
	Chrysemis marginata	..	..	..	x	x	2
	Sandpiper	x	..	..	..	..	1
	Total Vertebrata	1	6	6	2	5	
Algæ	Merismopedia	..	..	x	..	..	1
	Pediastrum	..	..	x	..	..	1
	Scenedesmus	..	..	x	..	..	1
	Closterium	..	..	..	x	..	1
	Total Algæ	..	..	3	1	..	..
Total species		43	41	39	23	..	50

Turning now to the plankton, the striking feature shown by the quantitative plankton summary, Table 25, page 474, is a progressive diminution in the total number of individuals per hundred liters, as one passes from the youngest to the oldest member of the series. The figures as given include both the phytoplankton and the zooplankton but even exclusive of the phytoplankton the same relative totals exist. As between the youngest and the oldest pond it will be seen that in the one year pond 99 per cent of the total is composed of protozoa and rotifers, while in the thirty year pond entomostraca comprise 85 per cent of the total. In the fifteen year pond entomostraca form a larger percentage of the total although only slightly so. In the ten year pond entomostraca are the most abundant group and are also more numerous than in either of the younger ponds.

The distribution of *Ceratium* throughout the series is most interesting. This protozoan was present in successively and sharply decreasing numbers with increase in the age of the pond. There were enormous numbers of it in the one year pond. In the five year pond there were only one-fourth as many and in the ten year pond there was a sharp decline from this reduced number to scarcely one-fifth of it. This one-fifth was reduced by fifty per cent in the fifteen year pond. In the thirty year pond there was only a trace of Ceratium. Apparently, then, Ceratium found its optimum conditions in the two younger bodies of water. That this condition is a matter of age rather than of distribution or location merely, is borne out by

TABLE 25.
Summary of Quantitative Plankton Results per 100 Liters.

Species	Ponds				
	1 Year	5 Year	10 Year	15 Year	30 Year
Ceratium longicorne	850,000	203,125	11,160	5,250	Trace
Rotifera	4,500	2,231	10,892	5,750	2,000
Arcella vulgaris	4,000	6,250	Few	5,375	Few
Nauplius	15,625	7,500	55,800	Few	2,250
Dinobryon	1,325,000	....	....	....	....
Cyclops	2,000	....	....	....	....
Chydorus	....	6,696	....	....	....
Daphnia	1,500	2,000	....	....	....
Blue-Green algæ	....	....	685,250	....	....
Pediastrum	....	....	17,850	....	....
Pleodorina	....	....	67,000	....	....
Cypris inequivalva	....	....	....	5,890	....
Cypris sp	....	....	....	6,250	....
Closterium	....	....	....	535,750	....
Potamocypris	....	....	....	5,000	1,000
Cyclops ater	....	1,000	....	....	....
Bosmina longirostris	....	750	....	....	6,300
Scapholebris	....	....	....	....	1,250
Ophryoxus	....	....	....	....	2,250
Ceriodaphnia	....	....	....	....	2,250
Total number of individuals	2,199,125	225,802	847,952	569,265	15,300

the fact that the one, ten and thirty year ponds are within half a mile of each other, whereas the one and five year ponds are five miles apart and in somewhat different surroundings. Furthermore, towings taken at various intervals during the summer for three years, showed that the differences were not merely a matter of pulse.

In general, then, it can be said, regarding the zooplankton, that the percentage of entomostraca increases with age and in the older ponds, forms the greater part of the plankton animals, although the data do not show an absolute increase in numbers. On the other hand, the protozoa and rotifera form the greater part of the zooplankton in the two younger ponds.

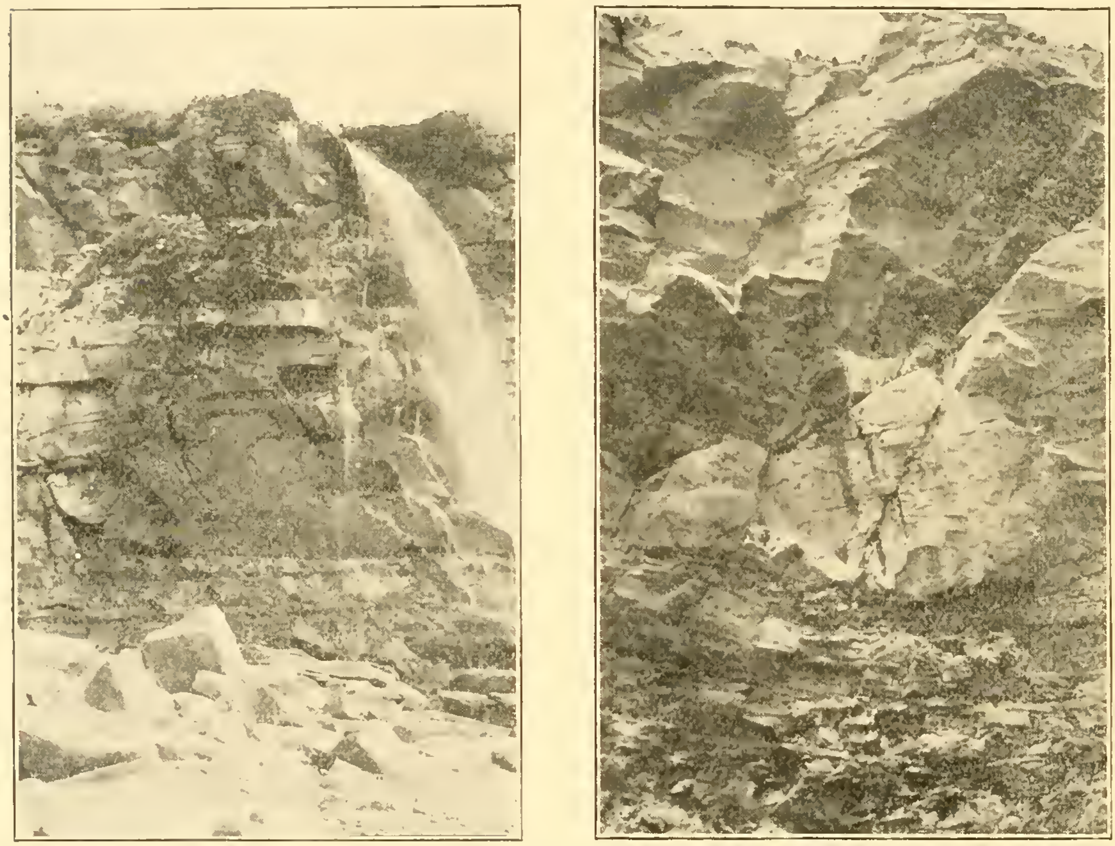
X. BIRDS OF THE KATMAI REGION.*

James S. Hine.

Most of the birds taken by the expedition were procured near the mouth of the Katmai River. Water birds predominate in the region because a better food supply is available for them than for the land birds. Most species are represented by a large number of individuals, and for that reason there are large numbers of birds although not a great many different kinds. Kashvik Bay, the southern part of Katmai Bay, is the feeding grounds of thousands of gulls and related forms and an immense amount of food is required to feed them.

Since the time at my disposal did not allow the making of a complete collection of the birds of the Katmai district a complete list is not possible at this time, and since it is the plan to list only the species taken and many of the characteristic birds are not represented a few notes on the commoner Alaskan birds precede the others.

One of the noisiest birds the summer through was the common loon of the region. Specimens were seen commonly and often passed overhead uttering their hoarse and homely notes giving the suggestion of nearness to a farmyard with domestic ducks in full song. The red-breasted Merganser is a common species in the region and adults with young were seen on more than one occasion. The young are expert swimmers and are very difficult to capture, even when only a few days from the egg. The species was very quiet about its haunts at all times and was observed only when we came upon it without its knowing of our approach. During the last days of August many well organized flocks of geese and swans passed over our camp. The bald eagle was seen at various times. This was one of the few birds observed flying over the Valley of ten thousand Smokes. It was not flying high but apparently was not inclined to linger over and was soon out of sight in more productive territory. The raven is widely distributed in Alaska and one is nearly sure to hear their notes wherever he happens to be. Several pairs nested on the rock shelves of the sea wall near our base camp. The young were able to leave the nest during the first part of July. Snowflakes were often seen on the tops of peaks, and in Katmai Canyon members of our party found them on several occasions. Along the upper course of Mageik Creek we saw a pair of these birds and heard them sing. We had been on the trail for hours without seeing either animals or



Two views of the sea wall along Katmai Bay. View at left shows nesting site of the Glaucous winged Gull; at right, of Pelagic Cormorant.

plants; suddenly in the distance we heard the song of the male snowflake and as we proceeded on our way the song became clearer. Finally we came to an immense spring of clear water which it seems had been the means of preserving a few bunches of grass at its outlet and the pair of snowflakes had found them. These bunches of grass were the only green plants we had seen for miles and their presence associated with the singing bird and its mate gave a feeling of pleasure which was very much appreciated.

Fratercula corniculata (Naum.). Horned Puffin.

A species often observed. Nests were located in crevices of the rocks of the sea wall. Hundreds of pairs were seen and when walking along the beach below the sea wall when the tide was low one could see specimens every few feet flying from their nesting sites. Specimens appeared to use crevices in the rocks as security from storms and natural enemies or as places in which to rest as well as for nesting places.

Cephus columba Pal. Pigeon Guillemot.

Common. Nests in the crevices of rocks like the puffins. Often seen in flocks of a half dozen or more resting on the surface of the water. A series of specimens shows variations from those very much mottled with white all over to black with a large white spot on each wing. They utter a shrill whistle when frightened and resent being approached too closely.

Rissa tridactyla pollicaris Ridgw. Pacific Kittiwake.

We did not see these birds at Katmai until about the tenth of August when they appeared in large flocks. At times they composed a large percentage of the gulls present in Kashvik Bay. Flocks of hundreds were seen together commonly.

Larus glaucescens Naum. Glaucus-winged Gull.

This very large gull was common on the Katmai coast during our whole stay in the region. They nested all along the sea where the rock wall was present. Soon after our arrival they began nesting and before we came away the young had grown to full size and were about with the old ones. The adults are very noisy birds, especially in the vicinity of their nests. Ravens, foxes and other animals are their enemies and keep them in a state of uproar most of the time. Their notes often become a source of annoyance for so long as one remains near the shore he is never out of the sound of their voices. Many nests were located and it was found that they lay from two to three eggs, usually on shelves of almost inaccessible rocks but at times on top of the cliffs where they can be reached easily from above. The young remain among the rock crevices and run under cover when they realize they are observed. We constructed an improvised ladder to use in studying the nests, eggs and young, and were able to see many of them. Often when the young could not find a crevice large enough to hide their whole bodies they would be satisfied with hiding their heads and covering their eyes. They grew rapidly and their homes became very foul smelling abodes for the parents appeared to keep them well supplied with an abundance of food which consisted mainly of the common brittle shelled clam, Siliqua patula Dixon, and often when I climged to their nests I found their runways strewn with numbers of partially eaten representatives of this species in different stages of decomposition.

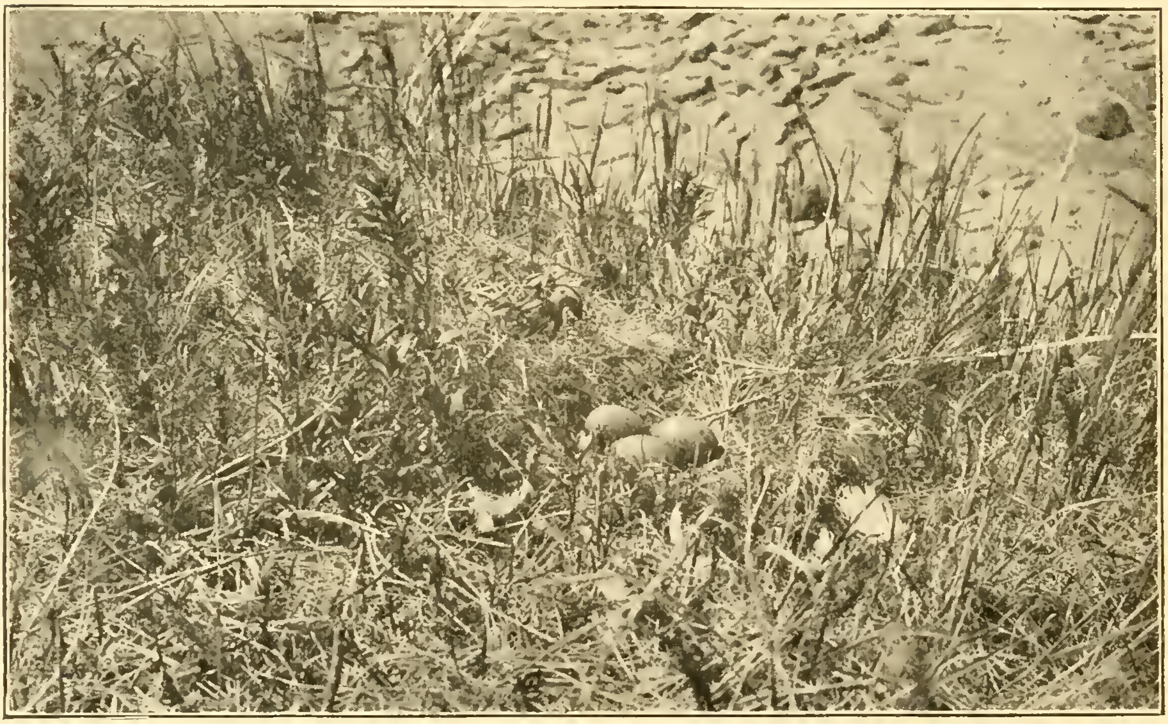


Photo by J. D. Sayre

Nest and Eggs of Glaucous Winged Gull.

Larus canus brachyrhynchus Rich. Short-billed Gull.

Numbers of this species were among the thousands of specimens of gulls to be seen about Kashvik Bay during the latter half of August. A specimen in immature plumage was taken August 23d.

Larus philadelphia (Ord.). Bonaparte Gull.

About the first of August large flocks of this gull appeared about the rich feeding grounds of Kashvik Bay. Several specimens were taken on the second of August.

Phalacracorax pelagicus Pallas. Pelagic Cormorant.

Colonies of this cormorant nested on the shelves of the sea wall along Katmai and Kashvik Bays. Several nests were investigated and several sets of eggs taken. The eggs do not differ in any particulars from the eggs of other cormorants and a set is three or four usually. The nests are composed of slender grasses tightly packed together and matted so as to form a firm mass closely applied to the rock shelves which support them. The adults cling to their nests rather closely although some specimens are more easily flushed than others. These nests become rather repulsive before the young leave them for they remain in them for a long time and feed upon fish with which they are rather bountifully supplied by their parents.

Anas platyrhynchus Linnæus. Mallard.

The mallard is common in Alaska, especially in the fresh water lakes which abound in many places. These lakes often occur only a short distance back from the sea and many of them are exactly suitable for mallards. Adults and their young were seen frequently in June and the grown up young ones were seen and taken plentifully in August. There is no greater sport from the standpoint of the bird student than to come suddenly upon a brood of young mallards. The manner in which the mother manages the situation and the ease with which the young as well as the old one disappear from view are matters of interest from the standpoint of the observer. Usually, it is fairly easy to procure one of the young for a short study if a specimen is singled out and followed to its hiding place, but one need not be altogether discouraged if every one of the specimens succeed in eluding him, and there is left only the excitement of the very brief confusion into which the ducks are thrown by the surprise.

Mareca americana (Gmelin). Baldpate.

The American widgeon, as some of our hunters call it, was seen occasionally and specimens were procured from small bodies of fresh water near the mouth of Katmai River. The species does not appear to be as common in the region as the mallard.

Clangula islandica (Gmelin). Barrow Golden-eye.

Taken August 20, from a small lake. Observed at other times during the summer. From information gathered it is a rather common species in the region.

Histrionicus histrionicus (Linnæus). Harlequin Duck.

This species was always taken in immature plumage and is one of the commonest species of the region. Flocks were frequently observed swimming in open sea water or sunning themselves in quiet coves along the shore. The people of Alaska call them Kommonuskies and they are supposed to be very hard to shoot. They rarely fly when shot at but dive instead and returning to the surface within a few feet quite rapidly move out of range.

Somateria spectabilis (Linnæus). King Eider.

Hundreds of ducks were seen far out in Katmai Bay on different occasions apparently lined up as if engaged in systematic fishing. It was not possible always to be sure of the species of duck concerned but we were reasonably sure that more than one was thus engaged sometimes. Specimens of the King Eider were taken near the mouth of the Katmai River, June 25. There is very good reason for believing that other eiders and some of the scoters, at least, take part in the systematic fishing operations of the region, but as none but the King Eider was taken, the statement has to be based upon field observations which are not altogether trustworthy because the birds were never close enough for accurate identification.

Phalaropus lobatus (Linnæus). Northern Phalarope.

Seen in small flocks swimming in pools adjacent to the mouth of Katmai River, July 25, and specimens taken. Flocks were seen on different occasions over a period of three or four weeks. They are very quiet birds, only uttering peeping sounds which may be heard only when one is near them. They never showed a great deal of fear, allowing one to approach within a few feet before taking wing. They swim easily and make an attractive appearance in the water.

Arquatella maritima couesi Ridgeway. Aleutian Sandpiper.

Several specimens of this bird were seen along the sea shore among the stones. Three specimens were taken August 20 to 23. Only two or three specimens were seen at any one time.

Pelagic Cormorant at right; Horned Puffin at left.

Pissobia minutilla (Vieillot) Least Sandpiper.

A few specimens were observed on the beach near the mouth of Katmai River and one specimen was taken July 23.

Pelidna alpina pacifica Coues. Red-breasted Sandpiper.

One specimen taken August 23, on a sandy beach near the mouth of Katmai River. I did not find it in numbers at any time.

Ereunetes mauri Cabinis. Western Sandpiper.

Large flocks were common on sandy stretches of beach for several days. Taken July 23 and August 2, and observed frequently for a longer period.

Glottis melanoleuca (Gmelin). Greater Yellow-legs.

This species nests commonly along the coast of Katmai Bay and several pairs were seen. It is very noisy in the vicinity of its nest and young. Some pairs found something to scream about most of the time night and day. When some of our party were not passing their way it seemed that some animal or other was bothering. We often wondered when they found time to eat, and feed and care for their young. Their notes may be heard plainly for a half mile or more and during the time they think they are being imposed upon at their nesting grounds, they spend part of the time on the ground and part perched on the tips of the taller trees in the vicinity, and as they appear very nervous and change from one to the other often much time is consumed on the wing and the antics they perform in the air are difficult to describe. It was sport to tease them when we could do it as well as not without wasting valuable time for that purpose alone, but the birds proved to be so much more persistent than we were and seemed never to tire of screaming and performing air antics that we usually retired from the conflict and left the birds screaming long after we were thoroughly tired of their noise and more than willing to forget it.

Heteroscelis incanus (Gmelin). Wandering Tattler.

A pair of these birds was observed along a rocky coast on Katmai Bay, August 3. They took wing several yards ahead of us and alighted again further on, repeating the procedure several times and making their characteristic sounds every time they took wing, finally going far out over the water and dropping back behind us. One specimen was procured August 3, and another August 25, the latter a bird of the season with white under parts.

Charadrius dominicus fulvus Gmelin. Pacific Golden Plover.

Small flocks were observed on the mud flats and sandy stretches of Kashvik Bay. One specimen was taken August 24.

Arenaria melanocephala (Vigors). Black Turnstone.

This species first appeared along the shores of Kashvik Bay about the first of August, and increased in numbers later. August 25, flocks of a hundred or more were seen and at this time it was one of the most abundant shore birds in the locality. They are attractive birds and I enjoyed watching large flocks of them very much. Specimens taken show some variation in color and bear dates ranging from August 7 to 21.

Lagopus lagopus albus (Gmelin). Willow Ptarmigan.

Small flocks of this game bird were seen occasionally on the tundra in August feeding on berries. Earlier in the season adults and young were observed on the mountain sides. The species is known to be decreasing in numbers in many sections, because it is not well adapted for protecting itself against its enemies. Specimens that we saw made no great effort to get away and usually could have been taken without much trouble on our part. Specimens taken August 28.

Lagopus rupestris nelsoni Stejneger. Nelson's Ptarmigan.

The only specimen seen was taken on the mountain side just back from Kashvik Bay, August 23. It does not appear to be a common species in that section.

Falco columbarius Linnæus. Pigeon Hawk.

Commonly seen during the summer. One one occasion a magpie alighted near our tent in a much excited condition. Hearing it we undertook to determine the cause and soon saw a pigeon hawk perched in a tree only a short distance away. We shot the hawk and made a skin of it and it bears the date of July 25. A few days later what we considered two adults and four young of the season were observed on the wing circling above our heads on the south side of Katmai Bay. On the

Willow Ptarmigan above, fall plumage; Western Savanna Sparrow at right; Alaska Longspur at left.

15th of August on Kubugalki Peninsula, I picked up a pigeon hawk that had been in an encounter with magpies. The hawk received such severe treatment that it was unable to fly away and it allowed me to walk up to it. The single magpie which was engaging the hawk when I first realized that a fight was on flew gracefully away on my approach to join six others of its kind which, very likely, had been helping in a common attack upon their enemy.

Pica pica hudsonia (Sabine). Magpie.

The magpie is rather plentiful in the wooded areas of the region visited. They are mostly seen in small flocks of five to eight and there is evidence that they adopt this method for protection against their natural enemies. On various occasions these birds demonstrated that they had no great fear of man, for more than once I have seen them fly towards me and alight just a few feet away. From observation it is evident that the pigeon hawk, which is plentiful, is one of their much dreaded enemies, and not being able to find adequate protection from it in such a wild and uninhabited country they often engage it in combat to the finish.

Acanthis linaria (Linnæus). Redpoll.

This was one of the most attractive of the smaller birds seen in Alaska. Flocks of them began to appear about camp near the middle of July and soon they were everywhere, in the lowlands, on the mountains, in the wooded areas, along the streams and on one occasion I saw a large flock flying merrily about over the Valley of ten thousand Smokes. They appeared to be just as well satisfied one place as another and the wind and rain and the steam and unpleasant odors of the "Valley," so far as I could observe, detracted nothing from the pleasures they gave evidence of enjoying wherever they happened to be. During my stay in the Valley they were the only birds seen that gave any indication at all of being attracted by the unique conditions and unusual scenery to be observed. Whenever Redpolls are within hearing distance, whether on the wing or perched in the bushes, they are giving continually their soft twittering notes by which they are recognized readily. There is always an attractiveness about these notes that gives one a pressing invitation to go and see the birds. Specimens were taken on July 23.

Calcarus lapponicus alascensis Ridgeway. Alsaka Longspur.

During the nesting season the males of this species especially are very attractive both from the standpoint of their song and coloration. Nesting birds are plentiful on the tundra areas during the summer and as the plants in such situations seldom grow tall enough to hide even a small bird they appear regularly in full view perched on a slight elevation, often only a few feet away where they may be studied to the heart's content. It is splendid indeed to hear the beautiful song of the male and have him sitting where his every movement may be observed and his intense enthusiasm may be realized. As fall approaches, males, females and young of the season all seem to appear in modest plumage and associate in flocks and feed on the various low-growing berries and seeds of the region. In crossing the tundra at this sesaon one hears their characteristic peeps, often close at hand, but usually does not see the birds until they fly up only a few feet away and arise high into the air and flit beyond the vision. Specimens in nesting plumage taken July 12. Other specimens August 15.

Passerculus sandwichensis alaudinus Bonaparte. Western Savannah Sparrow.

One of the characteristic birds of the base of the Alaska Peninsula. Abundant in all favorable places and it seemed to prefer the grass covered areas adjacent to the coast and spent most of the time either on or close to the ground. They have a rather low note which one hears continually when in the vicinity of their haunts. The species was usually at its best toward evening when they were feeding. Although the species was common about the vicinity of camp it did not come around the tents as some of the other sparrows did. Specimens were taken June 22 and July 8.

Zonotrichia coronata (Pallas). Golden-crowned Sparrow.

The song of the Golden-crowned sparrow was very familiar about base camp as well as over much of the Alaskan territory visited. We found the nest often placed near a tuft of grass or in the midst of a bunch of dwarf willows. It is located and constructed much like the nest of our common song sparrow. Several pairs had nests near our tent and soon learned to depend upon crumbs from our table for food supply. Some specimens became so tame that they hopped about under the stools on which we were sitting and took pieces of bread which we dropped for them, or they alighted on the table and picked up crumbs about our plates and occasionally perched on our shoulders. Finally the young were old enough to leave the nest and came with their parents but would stand and squawk until the latter came with food. They developed rapidly and finally were able to come alone and soon learned to visit our store room and help themselves. As they became more and more meddlesome we tried to bar them from the tent but we did not succeed very well for they were quite handy in finding small openings that we overlooked. Up to the time we left they were making regular visits to our supplies and we found them to be much earlier risers than we were. I have often wondered what they did after we came away. The old ones ceased to come about regularly after the young were able to care for themselves and for a time we did not understand the reason, but one day we saw them looking very much tattered and worn. Molting time had come and apparently they were in partial hiding for their new plumage to develop. Specimen taken August 15.

Melospiza melodia insignis Baird. Bischoff's Song Sparrow.

A very common species inhabiting the rocky coast of Kadiac Island. Its chirp is much like that of our common song sparrow of eastern United States. It interested me especially because of its abundance and because it is much like a song sparrow we studied from the Katmai Bay region. Specimen taken September 12.

Melospiza melodia sanaka McGregor. Aleutian Song Sparrow.

A few specimens observed along the rocky coast of Katmai Bay. It is not quite so dark colored as the last but otherwise is much like that subspecies. Both are larger than the song sparrow we know in Ohio and both have longer and slenderer bills. Specimen taken July 25.

Passerella illiaca unalaskensis (Gmelin). Shumagin Fox Sparrow.

We found these birds in the margins of wooded areas and specimens came to our tent on various occasions to pick up crumbs for food. They were very quiet and retiring in habits, although they did not show particular fear. One or two specimens became quite tame and gave us an opportunity to study them closely. They were of more than ordinary interest on account of their shyness. One specimen taken July 9.

Dendroica æstiva rubiginosa (Pallas). Alaska Yellow Warbler.

We did not see a great many warblers in Alaska, although we did not procure all the species we observed. This one was often seen in the wooded areas near camp on Katmai Bay, and it most likely nested but the nest was not found. Specimen taken July 12.

Wilsonia pusilla piliolata (Pallas). Piliolated Warbler.

This was the most plentiful warbler of the locality. Many pairs were seen in the wooded areas near base camp, and there was every indication that they were nesting although the nest was not observed. Specimens taken July 12 and 23.

Anthus spinoletta rubescens (Tunstall.) Pipit.

Not noted until about the first of August when many specimens were observed on the dry sandy beaches that occurred in places along Katmai and Kashvik Bays. The species continued to be common during the remainder of our stay in the locality and I became much interested in observing it as we came and went about our daily affairs. It has a characteristic note which it gives regularly and which makes its determination easy for one who learns to know it. Specimens taken August 10.

Penthestes atricapillus turneri (Ridgeway). Yukon Chickadee.

Flocks of this species appeared in the wooded areas about base camp just before the middle of July. It reminds one much of the Chickadee of Ohio and I felt that I was within hearing distance of an old acquaintance when I first heard its notes. The birds were molting in July and many of them appeared much worn. Specimens were taken July 12.

Hylocichla guttata (Pallas) Alaska Hermit Thrush.

We did not observe this bird often and do not consider that it was common in the region. A specimen was taken July 25, at the extreme east end of Katmai Bay in a very wild locality where evidences of bears and wild animal life were abundant. I take it that the species nested here although the nest was not observed.

UNUSUAL DICHOTOMOUS BRANCHING IN VERNONIA.*

John H. Schaffner.

During the summer of 1918, the writer observed a remarkable occurrence of dichotomy in the stems of the ironweed, *Vernonia baldwinii* Torr. (*Vernonia interior* Small). Large numbers of stems were found that had a perfect dichotomy occurring at various heights from the ground to near the top of the inflorescence. The writer has observed isolated, individual cases of such two-forked branching or twinning in other plants, as for exemple in the inflorescence of *Chætochloa viridis* (L.) Scrib. and *Lacinaria punctata* (Hook.) Ktz. But such examples have been exceedingly rare.

Since the study of abnormal developments has received a new importance in practical investigations on heredity, it was thought worth while to make a record of the facts observed. At Morganville, Clay County, Kansas, several hours of superficial search along two ravines for about a mile resulted in the discovery of 81 such stems, mostly belonging to different individual plants. This *Vernonia* is a crown-former, sending up a number of shoots each year which are usually unbranched below the inflorescence unless injured, when abundant branching occurs of the usual monopodial type from buds in the leaf axils. The shoots are usually from 1—6 feet high and the inflorescence is much branched.

The division of the bud begins by a widening of the stem which soon becomes grooved on the two sides and after some inches of this double or twin structure gives rise to two usually separate branches. It is rather difficult to observe the plants rapidly because the dichotomous shoot may be hidden by neighboring, normal ones but the abnormality is nevertheless very striking. Only one clump was found in which all the stems were dichotomous and this individual had but three shoots. Usually one or occasionally two shoots are dichotomous in a clump. Sometimes a shoot is forked a second time above either in one or both branches and it is interesting to note that in all such cases found the second dichotomy is at right angles to the first.

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* Papers from the Department of Botany, The Ohio State University, No. 110.

FIG. 1. Pressed shoots of *Vernonia baldwinii* Torr., showing dichotomous branching. The third specimen shows each primary branch forked a second time at right angles to the first.

A very few plants were found with fasciated stems. Fasciation was exceedingly rare when compared with the dichotomous branching. One shoot was found which was both fasciated and dichotomously branched and which also had a number of twin and forked leaves. The forked leaves have dichotomous midribs.

At Emporia, Kansas, 24 plants were found with dichotomous stems in a narrow strip through a pasture about one-half mile long. Near Meriden, Kansas, north of Topeka, 55 plants with the dichotomous shoots were found, as the result of a short search in two pastures. Some of these were also twice forked.

These three stations are about 90 miles apart each way and it is evident that the dichotomous sporting is not local but probably is a characteristic of the entire species, occurring regularly in a given percentage of individuals. From the fact that more commonly only a single shoot among a half dozen or so, which develop on a fair sized individual, is dichotomous, it appears probable that in some years an individual might have forked shoots and in others not. This might easily be observed in transplanted individuals.

Dichotomous systems are extensively developed in the thallophytes, as in the red and brown algæ and also in the gametophytes of the *Bryophyta*. Among sporophytes of the higher plants the monopodial system of branching or some modification of it, namely, a true lateral branching system, is almost universal, except in the *Lepidophyta* where a remarkable dichotomous system was developed, as represented in *Lycopods* and *Selaginellas*. In the great tree forms of *Lepidodendron* and *Sigillaria* the repeated dichotomy of the crown and of the root system forms a truly remarkable type of tree when compared with our present trees with monopodial or sympodial systems.

Now it appears exceedingly interesting to the writer that such a dichotomous system should be developed in the ironweed which we may assume has had its monopodial character for millions of years and must have had a purely monopodial ancestry from the beginning of a branching system in the sporophyte. It is a dichotomous factor added in the presence of a monopodial factor of stem development. In the case of the *Lepidophyta*, the dichotomy was probably originated in a plant without any branching ability whatever in the stem. The *Lepidophyta* are far isolated in many characters from all other vascular plants.

It is possible that a dichotomous system might become normally hereditary in *Vernonia* but the present freak seems to be a case of ever-sporting or recurrent variation of the same nature as the fasciated cock's-comb and many other examples mentioned by De Vries. But from its wide distribution and abundant occurrence the writer is inclined to believe that this variation is a tendency of the whole species. There is a "bent" at least for the factor to be evolved if it is not universally present in a suppressed state. Whether the individuals that have dichotomous shoots would repeat the character more abundantly than those which are normal, as seems probable, can be determined by experiment. Of course, there may have been a primitive mutation which survived and became generally hybridized with the normal form. It may also be a case of double expression, something like the expression of lobed and unlobed leaves on a white mulberry tree.

Seed was not available at the time when the writer left Kansas for the east, but since one can find the dichotomous individuals so readily, seed can easily be obtained by any one at the proper season, because the character shows in the mature or dead shoots as well as in the younger stage of growth.

FACTORS CONTROLLING VARIATIONS IN THE RATE OF TRANSPIRATION.

J. D. Sayre.

While investigating the relation of hairy leaf coverings to the resistance of leaves to water loss,* a number of experiments were performed which show the relative effects of several of the principal factors controlling transpiration and the rhythm of the transpiration curve in darkness in mullein and tobacco. Because these experiments were not directly related to the subject of hairy leaf coverings and transpiration they are presented separately in this paper.

Historical.

Brown and Escombe[1] in their researches on static diffusion of gases showed that the stomatal openings of a leaf act the same as a multiperforate diaphragm in allowing water vapor to pass out from the intercellular spaces of the leaf. They showed that, in view of the number and sizes of the stomata, only about one-sixth of the possible diffusion of water vapor from the leaf of a sunflower (*Helianthus* sp.) is ever attained under ordinary conditions. Lloyd[2] came to the same conclusion in his experiments with ocotillo (*Fouquieria splendens*) and showed that when the stomata are almost closed their diffusion capacity is much greater than is needed even to allow a maximum transpiration. He concludes that the movements of the guard cells tending to open and close are not sufficient to account for the variations of water loss, under those conditions. He says, however, that complete closure (if it ever does occur) would function in controlling transpiration by eliminating the evaporation from the internal surface of the leaf and reducing the water loss to that from the cuticular surface. Livingston and Estabrook[3] found in a number of plants (*Funkia*, *Isatis*, *Allium Eichomia*, and *Oenothera*) that the stomatal movements were considerably more pronounced than would be expected from Lloyd's measurements. Other authors have found in their experiments on transpiration that

*Thesis presented for Degree of Master of Arts at the Ohio State University, Columbus, Ohio.

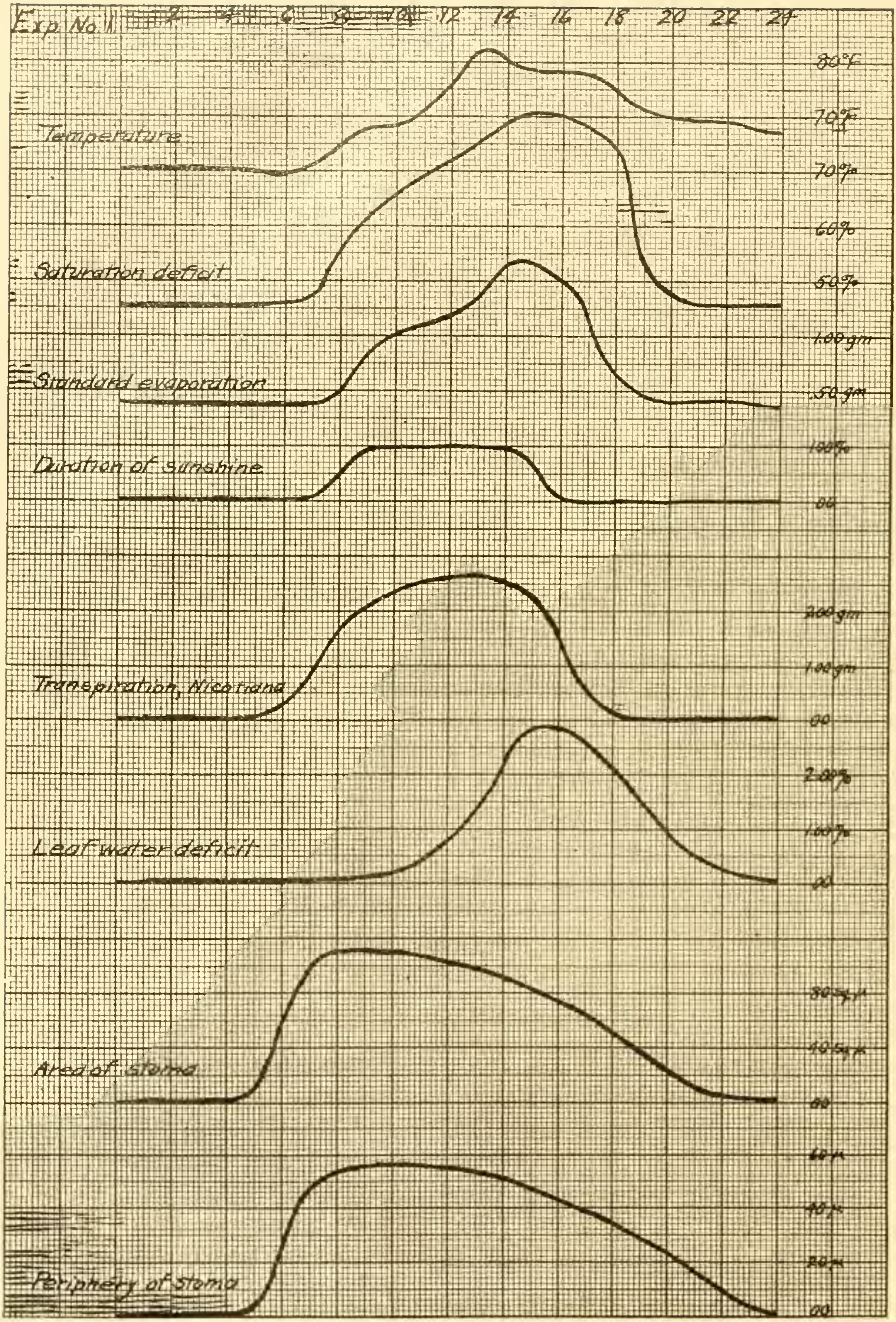

Fig. 1. Experiment 1.

many plants show a rhythm in the transpiration rates in darkness and attribute it to stomatal movements. Curtis[4] kept several plants under constant conditions in darkness and determined their hourly transpiration rates by weighing. He refers to the behavior of the transpiration rates as "a pronounced periodicity in the stomata." He made no direct observations on the stomata but concludes that this rhythm was due to their movements. Darwin[5] found by the indirect method of determining transpiration with a hygrometer that there was a rhythm in the transpiration rates in darkness and concluded that it was due to stomatal movements. Lloyd[2] found in "the plant (*Fouquieria splendens*) which he used that it behaves qualitatively the same in total darkness as under normal conditions until an hour (usually near 6 A. M.) when, the normal stimulation being absent, the plant relapses to a low condition of activity characteristic of its darkness condition. For the lack of a real explanation we must refer this behavior to the category of induced rhythm."

Lloyd measured the stomatal openings on different plants but could find no evidence that there was an increase in their dimensions corresponding to this induced rhythm. He concludes that some other factor than stomatal activity in the plant must be found to explain the transpiration curve. Livingston and Brown[6] found that in nine out of eleven plants which they investigated there was a decrease in the water content of the leaves beginning after sunrise and reaching a minimum a short time after the transpiration attains it maximum. This decrease was as much as 8% in some plants and did not produce wilting of the leaves. A decrease in water content of the mesophyll cells increases the resistance of the cells to water loss. Livingston[7] shows that some factor in the plant is operating to reduce water loss even though environmental conditions have not reached their maximum.

This summary shows that considerable work has been done on the effects of different factors on the transpiration curve; that no single factor has been found to control the rate of transpiration from the plant, and that transpiration is a resultant of the interaction of several internal and external factors.

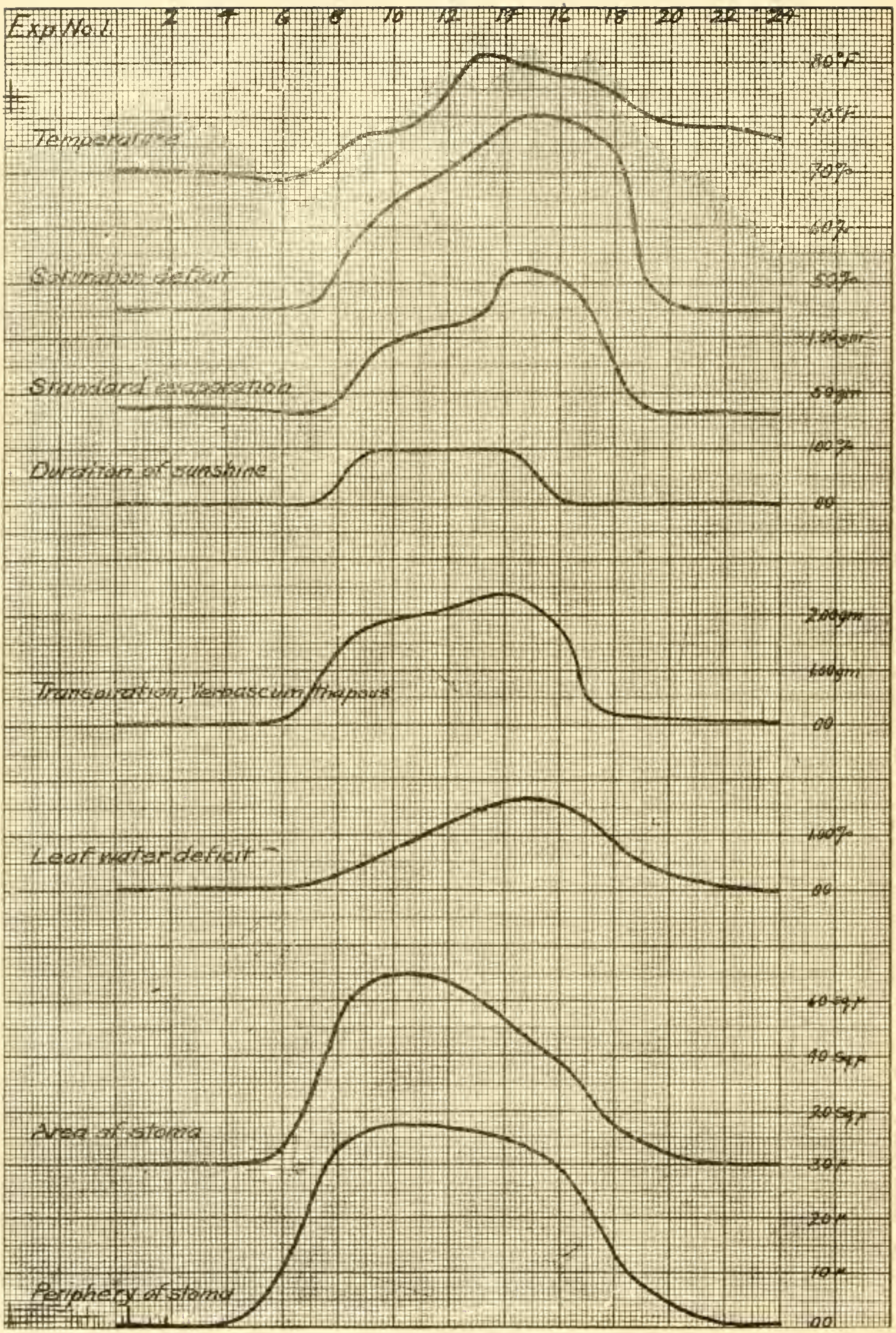

Fig. 2. Experiment 1.

Experimental Methods.

The experiments reported in this paper were performed under the direction of Dr. E. N. Tanseau in the Plant Physiology Laboratory of the Ohio State University. The apparatus used in determining the water loss from the plants, which has been described by Transeau[8], automatically records the loss of weight from sealed potted plants. In order to equalize light conditions in the greenhouse, the apparatus was mounted and operated on a rotating table. In the darkroom the apparatus was arranged on a laboratory table.

Records of the environmental factors influencing water loss from plants were obtained from instruments placed on the table with the other apparatus. The temperature and humidity of the air were recorded by a hygrothermograph, which was checked from time to time with a standard sling psychrometer. The evaporation rates were obtained from standardized porous cup atmometers. The record for the duration of sunshine was obtained from the U. S. Weather Bureau Station, Columbus, Ohio.

The water loss from the plants was measured as described by Transeau[8] from potted, irrigated plants. Leaf areas of the plants were measured at the beginning and at the close of each experiment and all rates of water loss are given as the rate from one hundred square centimeters of leaf area, considering one surface of the leaf. Leaf water content was determined by weighing and drying leaves from plants treated exactly like those used in the determination of the water loss. The sizes of the pore openings of the stomata were measured from strips of epidermis fixed in absolute alcohol as suggested by Lloyd[2] except that the calculation of the dimensions was different.

The results of the experiments given in this paper are expressed by curves because they give a better representation of what took place in the experiment, besides occupying less space and allowing more results to be placed together for comparison. A standard method for plotting the curves was chosen and all curves, as nearly as possible, made in that way. The times in hours, beginning with 1 for 1 A. M., to 24 for 12 o'clock midnight, are used as abscissae, five millimeters equalling one hour. The rates of transpiration per hour, or variations per hour are used as ordinates.

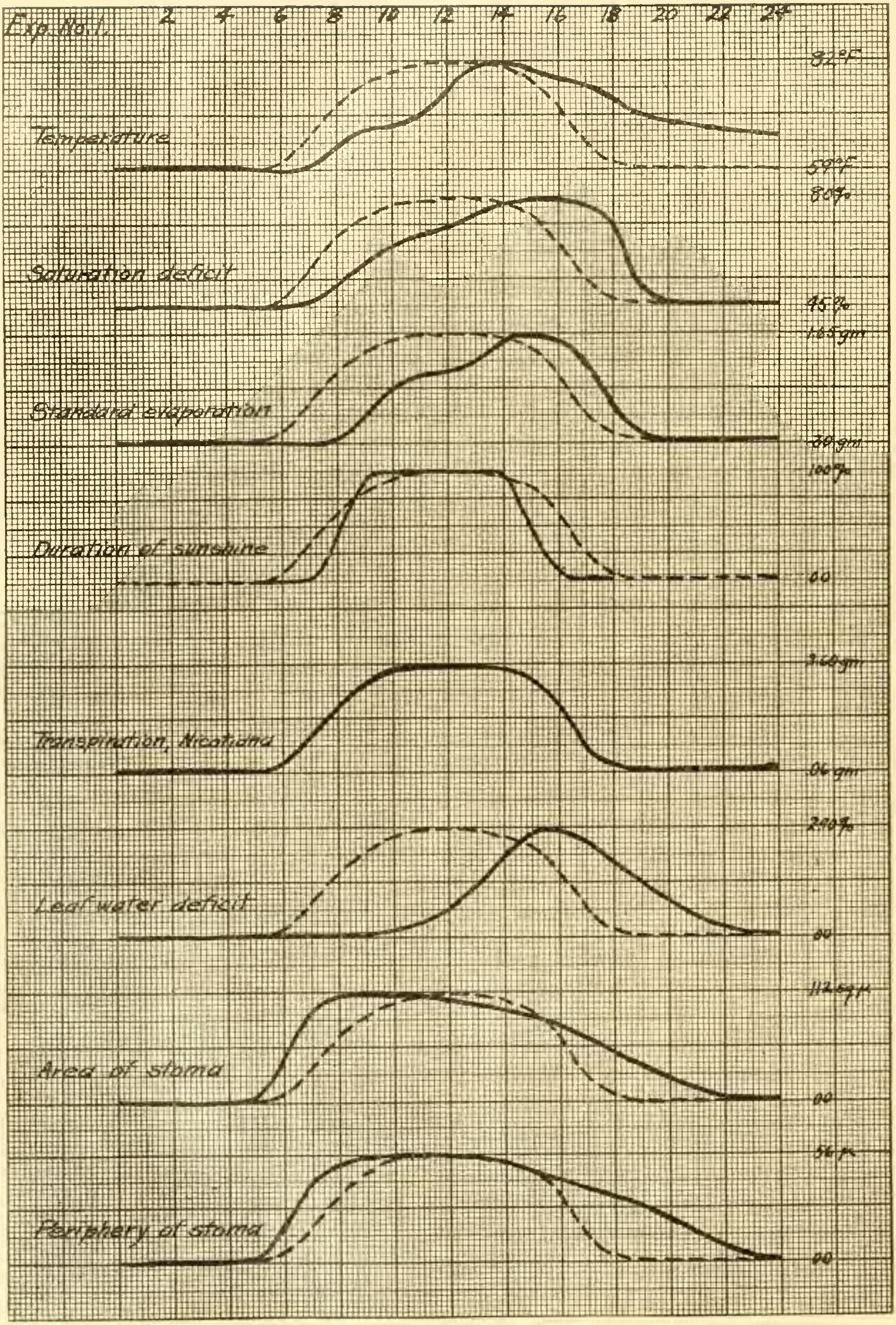

Fig. 3. Experiment 1.

The temperature is expressed in degrees Fahrenheit, and the humidity, reduced to saturation deficit (100%—% of humidity) is expressed in percentages. The evaporation is given as the rate in grams per hour of water loss from the Standard Cup, calculated from the coefficients furnished by the Plant World Company. Duration of sunshine is expressed in per cents per hour of possible sunshine. Transpiration is given as the rate in grams per hour of water loss from one hundred square centimeters of leaf area. Leaf water contents are reduced to leaf water deficits by substracting the figures for each from the maximum water content during the night, and are expressed in percentages. The areas of the stomatal pores and the peripheries of the stomatal pores are expressed in square microns and microns respectively.

Experiments.

In Experiment 1 the leaf water contents and stomatal movements of tobacco and mullein were measured, together with transpiration and the several environmental factors. These make possible a comparison of the effects of the various factors.

Five mullein (*Verbascum thapsus*) and five tobacco (*Nicotiana* sp.) plants were used in this experiment, one of each in determining the transpiration, and the other four in estimating the leaf water content and stomatal measurements. The plants were all sealed and irrigated, and were given special care for a week before they were used, and during the experiment they were exposed to the same conditions.

The apparatus for determining the transpiration was automatic and needed very little attention, while the leaf water content and stomatal measurements required hourly observations. The method of making these observations was to strip small pieces of the lower epidermis from the leaf, put them at once in absolute alcohol, and then cut the leaf from the plant and place it in an air tight weighing bottle. The leaves were weighed at once and dried to constant weight and the water content calculated from the results. The pieces of epidermis were mounted on a slide in absolute alcohol and outlines of a representative number of pore openings drawn on paper with a camera lucida. Later these outlines were measured and reduced to their actual size in microns. A polar planimeter was

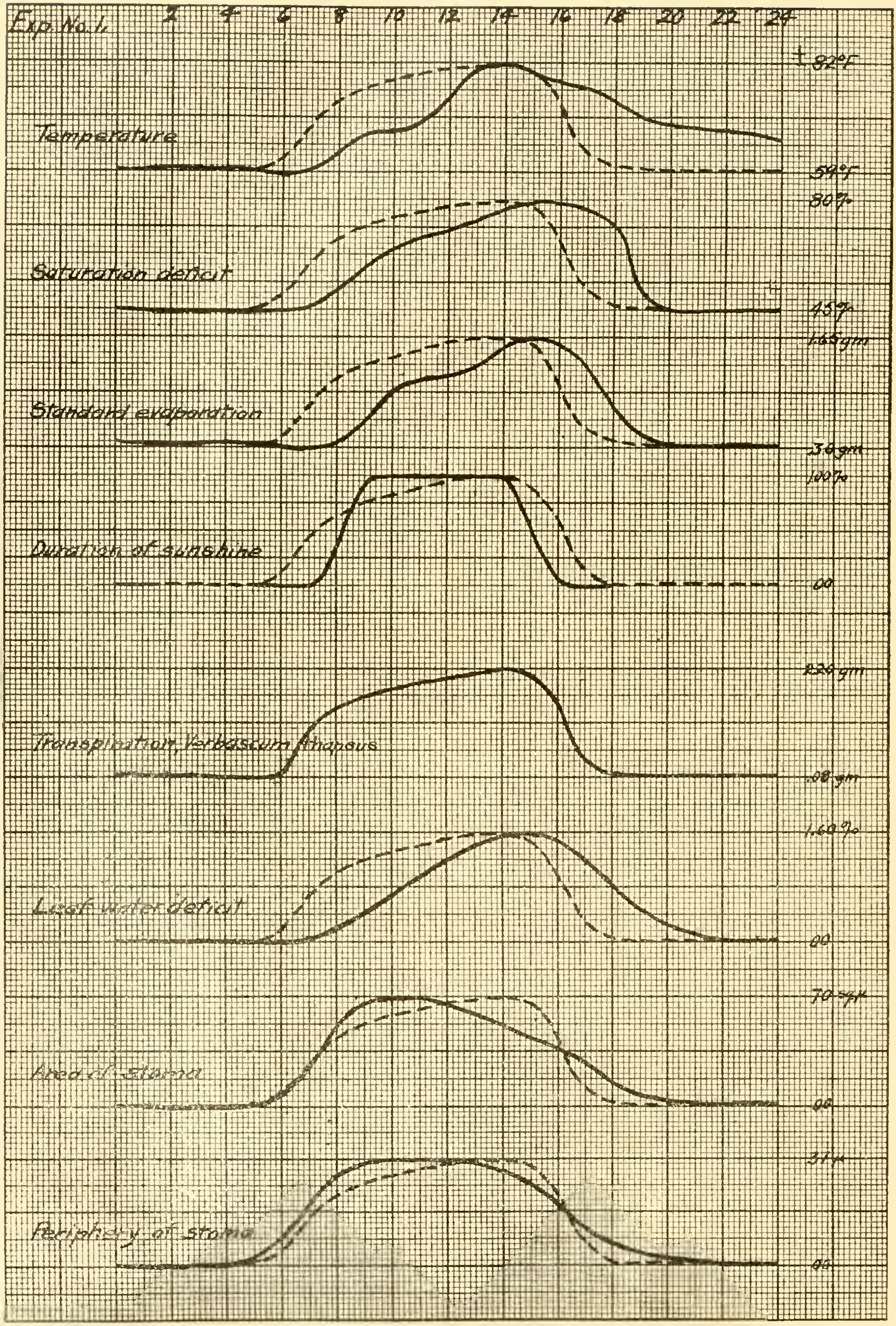

Fig. 4. Experiment 1.

used for measuring the areas of the openings and a small flexible centimeter rule for the peripheries.

In this experiment as well as in the preliminary work which was necessary to become familiar with the method, it was found that 85% or more of the stomata examined were closed at night, and as far as could be determined with the high power of the microscope this closure was complete and prevented gases from diffusing through them. In sunlight it was found that 90% to 96% were open. This difference is due, probably, to the fact that some of the stomata were fixed, or had ceased to open and close. Those that were found closed were regarded as zero in dimensions in calculating the area and periphery, and the results are expressed as an average of the number observed rather than the number found open. The results do not represent correctly the size of an average opening, because of their elliptical shape and the manner in which they close, but more nearly the average diffusion capacity of the stomatal area of the leaf. This method of observing and calculating the average size of the stomatal openings was followed in Experiment 1 and the results are given on pages 492 and 494.

These curves give the transpiration rates of mullein and tobacco, size of stomata, leaf water deficit and other factors of the environment. An inspection of these curves shows that the maximum temperature during the day occurs about the 13th hour and the maximum saturation deficit about the 15th hour. The maximum evaporation occurs about the 14th hour because it depends mainly upon the temperature and saturation deficit. The minimum of these factors occurs during the night.

The day was clear and quiet and there was full sunlight except for a short time, both in the morning and evening, when misty clouds occurred near the horizon. The transpiration curves began to rise about the sixth hour and rose rapidly until the ninth hour when the rise became more gradual until the maximum was reached at the 13th hour in tobacco and the 14th hour in mullein. This occurrence of the maximum rate of water loss before the maximum evaporation shows that some factor in the plant is operating to reduce water loss. The minimum of the transpiration curve occurs during the night. The leaf-water deficit began to rise gradually about the eighth hour and continued until a maximum was reached about the 15th or 16th hour when there was a decline to the usual amount by the

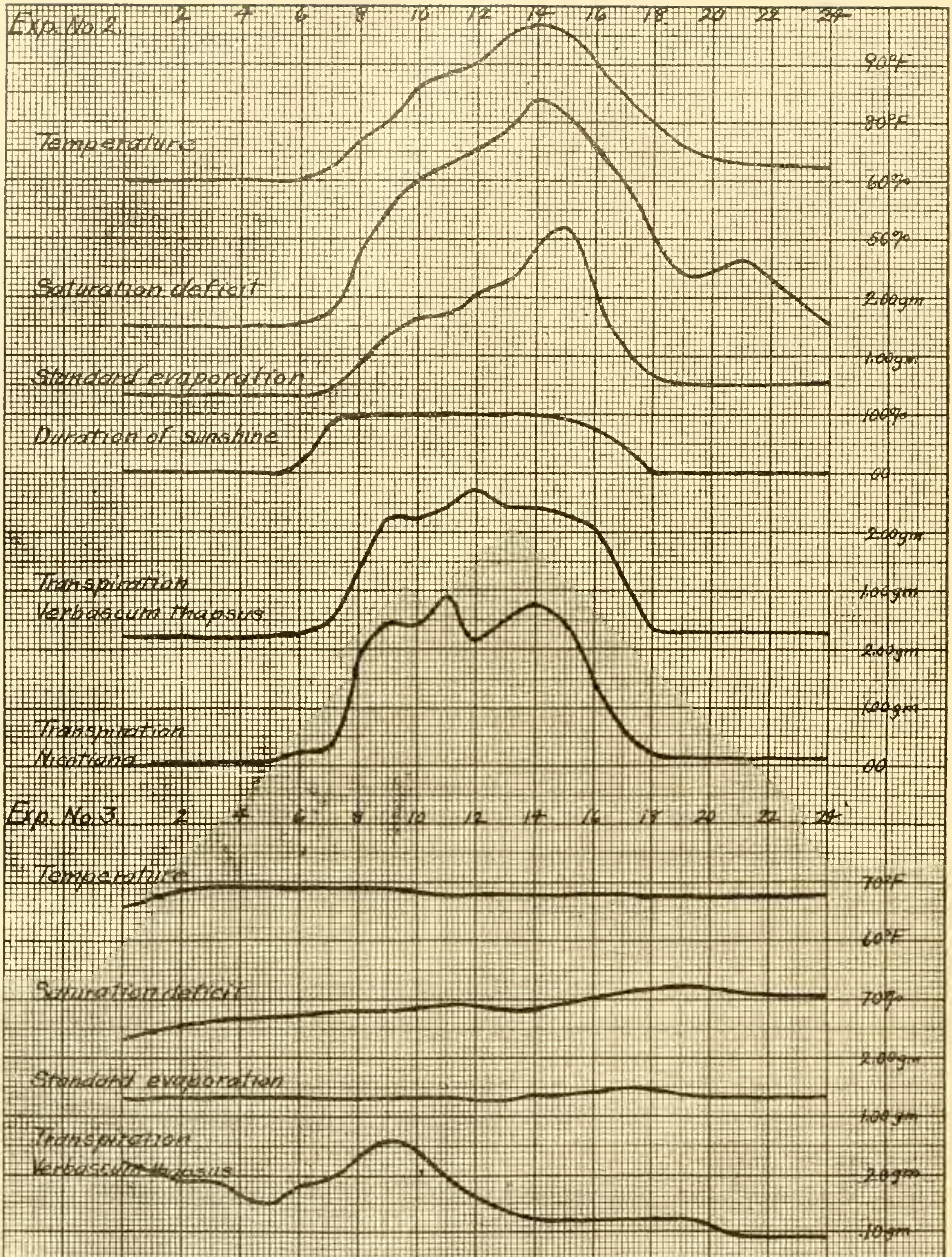

Fig. 5. Experiments 2 and 3.

22nd hour. The curves for the size of the stomata rose rapidly at the fifth hour, or sunrise, the hourly increment diminishing slowly until a maximum was reached at the 10th hour. From the maximum there was a gradual decrease until their night values were reached between the 20th and 22nd hour. It is apparent from the occurrence of the maxima of the different factors and the rates of water loss that no single factor controls the water loss from the plants.

A comparison of these curves does not give a true representation of their relations to each other because different scales of ordinates are taken in plotting them. For comparing curves of this kind the variation between the maximum and minimum values should be reduced to the same scale in all cases. The same curves are shown on pages 496 and 498 with the maximum and minimum values reduced to the same scale, and with the transpiration curve (dotted line) superimposed on each of the other curves. The maximum and minimum values of each curve are indicated on the base lines. A comparison of these maximum and minimum values shows that a change of 23° F. and 35% in saturation deficit of the air produced a change from 0.30 to 1.65 grams per hour in evaporation, *i. e.* increased it about five times. Under the same conditions of temperature and saturation deficit the transpiration rates showed a change from 0.08 to 2.20 grams per hour in mullein *i. e.* an increase of about 25 times and 0.06 to 2.60 grams per hour in tobacco *i. e.* an increase of about 40 times. It is obvious that so great a variation in the rate of water loss when compared with evaporation must be due to some physiological change within the plant.

An increase in leaf water deficit decreases transpiration by increasing the resistance of the mesophyll cells to water loss and as the maximum occurs a little later than the maximum water loss it operates to decrease the difference between the maximum and minimum rates of water loss. The stomatal openings are never used to their full diffusion capacity under ordinary conditions so the increase in their dimensions accounts for only the general difference between the day and the night rates of water loss. The rate of water loss from the leaf when the stomata are open is determined by the diffusion gradient (Renner,[9]), *i. e.*, the difference between the saturation deficit of the intercellular spaces of the leaf and the saturation deficit of the air.

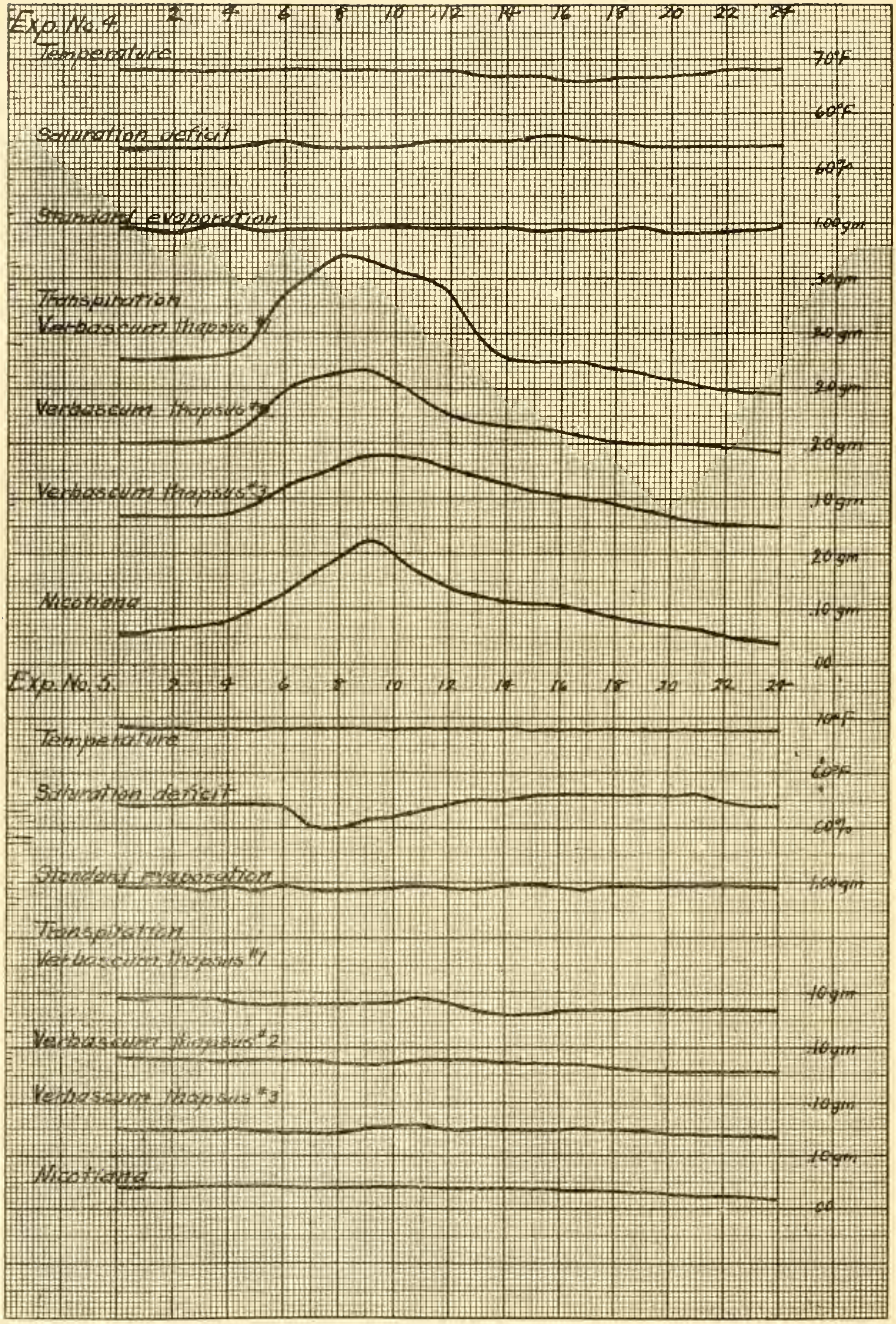

Fig. 6. Experiments 4 and 5.

The following conclusions concerning the limiting factors which control water loss from mullein and tobacco are based on Experiment 1. The diagrams on page 508 show the transpiration curves and the operation of these limiting factors. At night transpiration is limited to cuticular evaporation because the stomata are closed and the rate of water loss is determined by the temperature of the leaf and the humidity of the air, which were in these experiments nearly constant during the night. The process of water loss at night is simply and easily explained, but in the daytime the stomata open and there are changes in temperature and humidity due to sunlight which make the explanation of the process more difficult. The rate of water loss in the daytime is affected by the diffusion gradient of the stomatal pores although the cuticular transpiration still continues and is slightly increased by the rise in temperature and saturation deficit of the air. The increase in the rate of water loss during the morning hours is brought about by the increase in size of the stomatal pores, beginning about sunrise and the probable increase in diffusion gradient through the stomatal pores, resulting from the increased saturation deficit of the air. At about noon, there are two factors, leaf water deficit and decrease in stomatal pores, operating to diminish water loss from the leaf, and only one factor, diffusion gradient, tending to increase it. This results in a rounded curve and finally a steady decrease. The diffusion gradient becomes an additional factor tending to decrease water loss after the saturation deficit reaches a maximum and there are then three factors all operating in the same direction which cause the rate to quickly decline to the night level. Thus the water loss is reduced to the night rate, even though the stomata are not fully closed.

The stomata open normally every morning in sunlight and the normal transpiration curve shows a sudden rise at that time. The fact that the stomata open slightly but fail to open fully or to remain open if the plant is in continuous darkness in the morning has been inferred by Curtis and Darwin, who found a rhythm in the transpiration curve in darkness and concluded that it was caused by stomatal movements, but Lloyd, although he showed that an induced rhythm of the transpiration curve occurs in ocotillo, could find no corresponding increase in the size of the stomata. A number of experiments were performed which show this rhythm of the transpiration curve in mullein and tobacco.

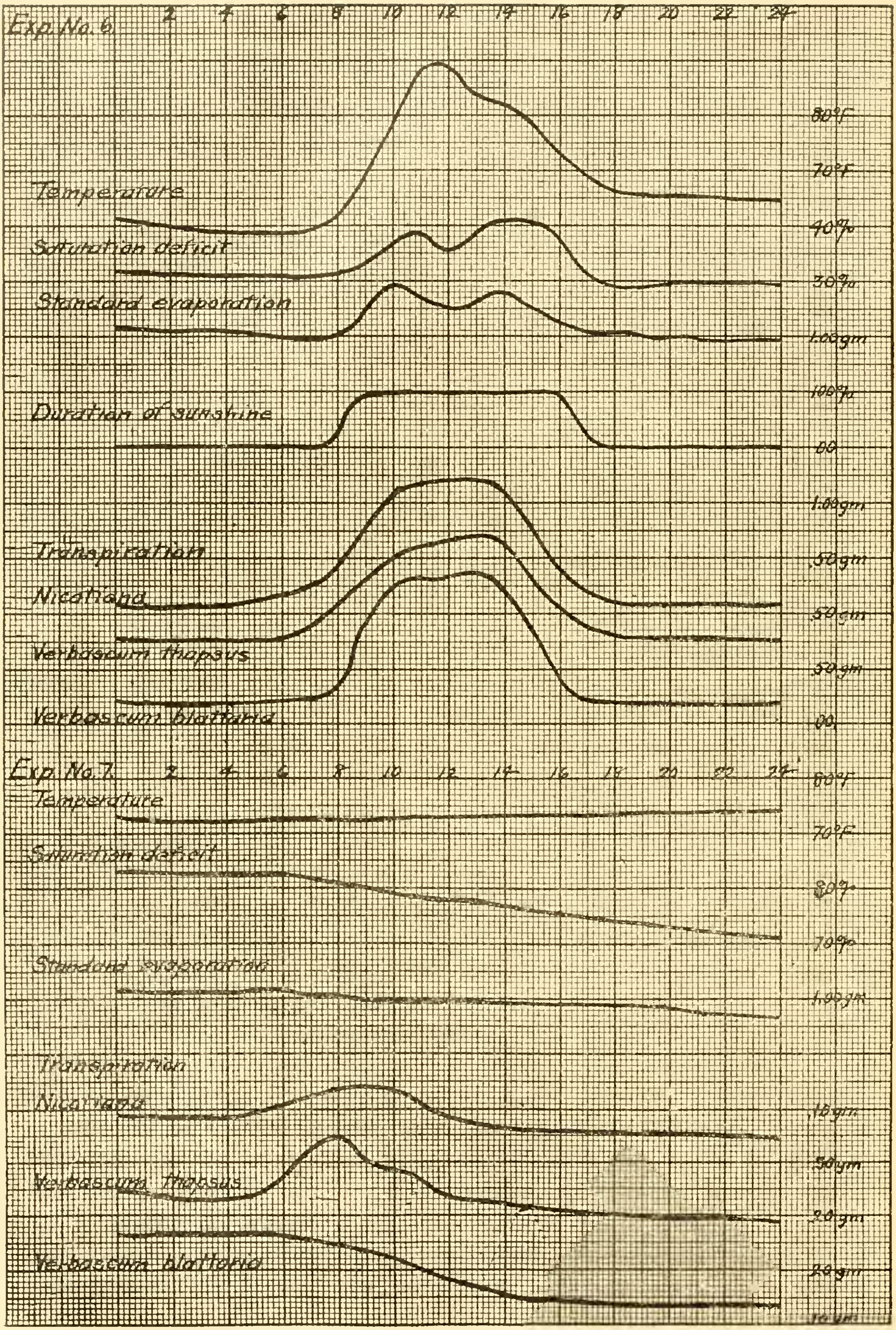

Fig. 7. Experiments 6 and 7.

Experiment 2: The curves for this experiment show the daily variation in transpiration of mullein and tobacco under ordinary conditions, with the environmental factors which influence water loss from plants. The transpiration rates show a rapid rise shortly after sunrise with high rates of water loss as compared with the night rates during the period of sunlight.

Experiment 3: This experiment shows the transpiration curves for the same two plants in a dark-room. The temperature, saturation deficit of the air, and evaporation were constant in the dark-room. But in spite of these constant environmental conditions the transpiration rates show a rise and fall or rhythm during the day. This rise in the rate of water loss begins about the time the stomata usually open or about the fourth or fifth hour and reaches a maximum about the ninth or tenth hour when there is a gradual decrease to the usual night rate by the middle of the day.

Experiment 4: In order to show that this rhythm was not characteristic of a single plant, different plants were put in the darkroom and their transpiration curves obtained. The curves from three mullein plants and one tobacco plant show this rhythm under conditions of constant temperature, humidity, and evaporation and in total darkness, which began, reached a maximum, and declined to the usual night rate similar to the curves of Experiment 3.

Experiment 5: The plants used in Experiment 4 were left in the dark-room and the curves for the second day under constant environmental conditions were obtained. There are no indications of a rhythmic rise and fall in the transpiration rates in this experiment.

Experiment 6: These curves show the hourly rates of transpiration and the related environmental factors in the greenhouse for three different plants, mullein, tobacco, and moth mullein (*Verbascum blattaria*). These plants have similar transpiration curves under these conditions. These mullein and tobacco plants were not used in any of the preceding experiments.

Experiment 7: These curves are from the same three plants that were used in Experiment 6, but they were obtained under constant environmental conditions in the dark-room. The curves for the rate of water loss from mullein and tobacco show

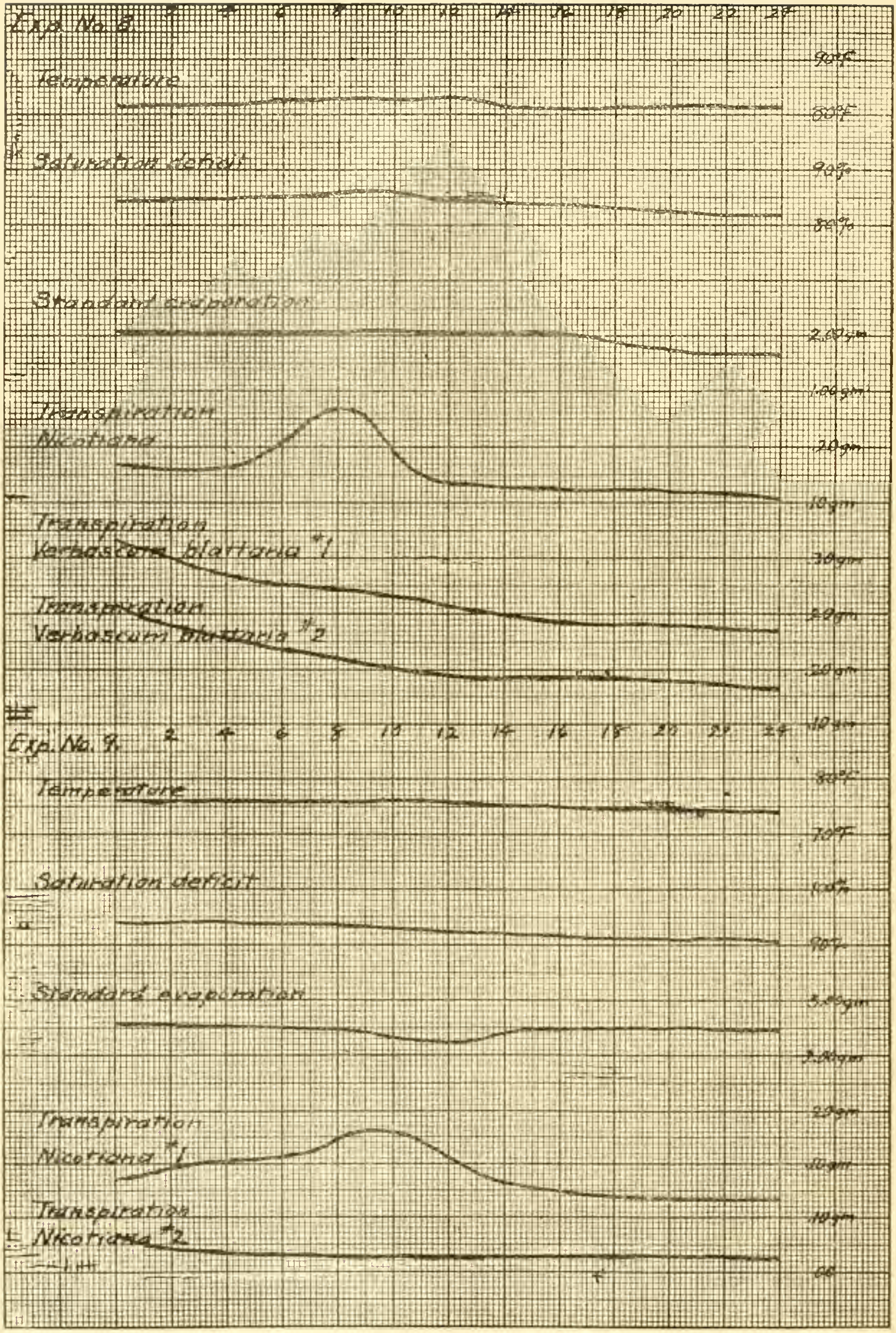

Fig. 8. Experiments 8 and 9.

rhythmic rise and fall similar to those from other plants the first day in the dark-room, but there are no indications of this rhythm in the rate of water loss from the moth mullein.

Experiment 8: To find out if the absence of a rhythm in the transpiration curve of moth mullein was a characteristic of that species or simply of an individual of the species, two more moth mullein plants and a tobacco plant were placed in the dark-room and their transpiration curves determined. But as in Experiment 7 under constant environmental conditions both of the moth mullein plants failed to indicate any rhythmic rise and fall in the rate of water loss, which showed a gradual decrease throughout the experiment.

Experiment 9: In this experiment the transpiration curves from two tobacco plants were obtained by placing Nicotiana No. 1 in the dark-room after sundown and Nicotiana No. 2 about noon of the preceding day. There was the usual rhythm in the transpiration curve in Nicotiana No. 1, but Nicotiana No. 2 showed no indications of this rhythm.

Summary of Results.

The experiments given in this paper show that the differences between the night and day rates of water loss from mullein and tobacco are largely due to the differences in diffusion through the stomatal pores. Transpiration from the leaves at night is entirely cuticular and its rate is controlled by the temperature and humidity of the air when the stomata are closed. But the day rate is controlled by a number of factors operating to increase or decrease it. When the stomata open the diffusion gradient, or the difference between saturation deficit of the intercellular spaces and the atmospheric saturation deficit, causes a sudden rise in the rate of water loss. This rate continues until the leaf water deficit probably decreases the diffusion gradient by increasing the resistance of the leaf to water loss. After the leaf water deficit reaches a certain point there are two factors, leaf water deficit and decreasing stomatal pores, operating to reduce water loss. There is only one factor, diffusion gradient, tending to increase it. This results in a rounded curve as shown in figure 9. After the saturation deficit reaches a maximum all three factors operate to decrease the rate of water loss. This results in a rapid decline in the rate,

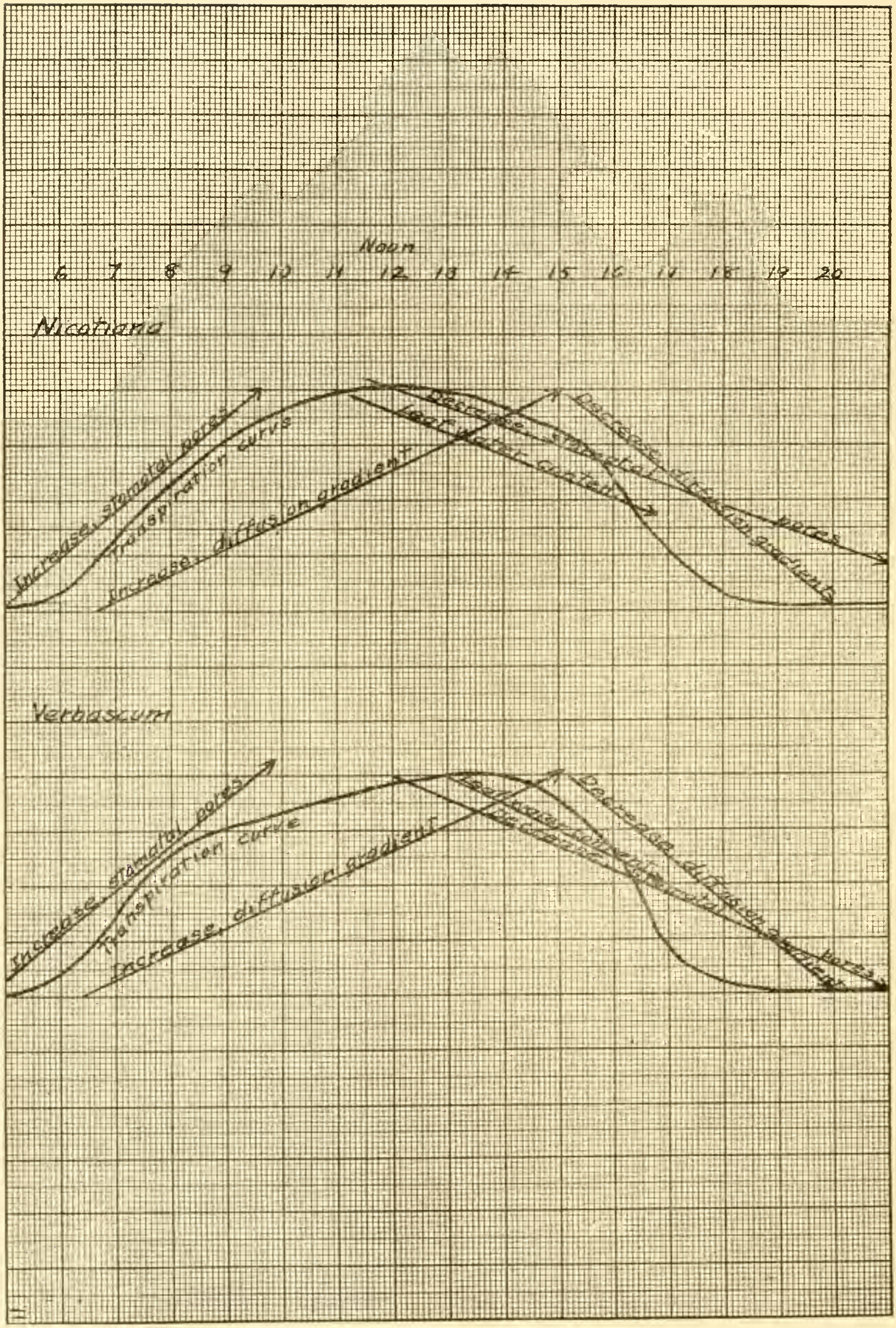

Fig. 9. Diagrams showing factors which modify the rate of transpiration.

even before the stomata are fully closed. The decreasing leaf water deficit has no effect after the stomata are closed.

Tobacco and mullein show a rhythm in the transpiration curve in total darkness when preceded by a day of normal light conditions, while moth mullein under the same conditions does not show this rhythm. This rhythm is expressed as a rise in the rate of water loss at about the time the stomata usually open in sunlight with a maximum about the middle of the forenoon and a decrease to the usual night rate by noon. This takes place in total darkness under constant environmental conditions. The rhythm in tobacco and mullein does not show up on the second day in the dark-room, and in tobacco which is placed in the dark-room about noon of the preceding day there is no rhythm in the transpiration curve. The moth mullein does not show this rhythm under the same conditions. It seems therefore, that certain plants have this characteristic rhythm while others do not. The cause of the rhythm is most likely stomatal activity but because of the large errors in measuring these movements as compared with the small movement necessary to produce the slight increase in transpiration it has not been found possible to verify it.

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THE USE OF CHICKS IN VITAMINE TESTS.

R. J. Seymour and E. P. Durrant.

The animals most frequently used for tests on vitamines have been rats, mice, chickens and pigeons. While these animals may possess some advantages yet their use also presents some difficulties in the average laboratory. Rats and mice must be kept well past the suckling stage in order that feeding tests may be made. For such tests pigeons and chickens must be kept in larger numbers and in more commodious quarters than are usually available. Such disadvantages led to the trial of chicks for the purpose of demonstrating to the classes in elementary physiology the role of vitamines in a diet. Chicks were chosen for the test largely because no special cages were necessary, because the rate of growth in the chick is rapid, and the amount of care and attention required is slight.

Because of their reputed hardiness Leghorn chicks were selected. They were purchased as "day-old" chicks (available at almost any season) and were placed in a suitable attic room, heated by hot water and with a large skylight. No attempt was made to keep the temperature constant, although the range was not great usually being between 65° and 75° F.; however, the chicks could hover in an enclosed box beneath the hot water pipes. Until they were a week old additional warmth was supplied by an electric bulb. Water, shell, and grit were constantly available. Foods containing practically no vitamines were placed in a self feeder and all chicks had access to this at all times. Such food consisted of rice flour, highly milled corn meal, and patent or highly milled wheat flour. These were presented to the chicks in a variety of ways and combinations. The more usual method being to have these flours baked into small unleavened loaves which were then dried and ground into crumbs. The only care found necessary in carrying out the test was to see that the food combinations were changed frequently enough that the chicks continued to eat freely of the food offered.

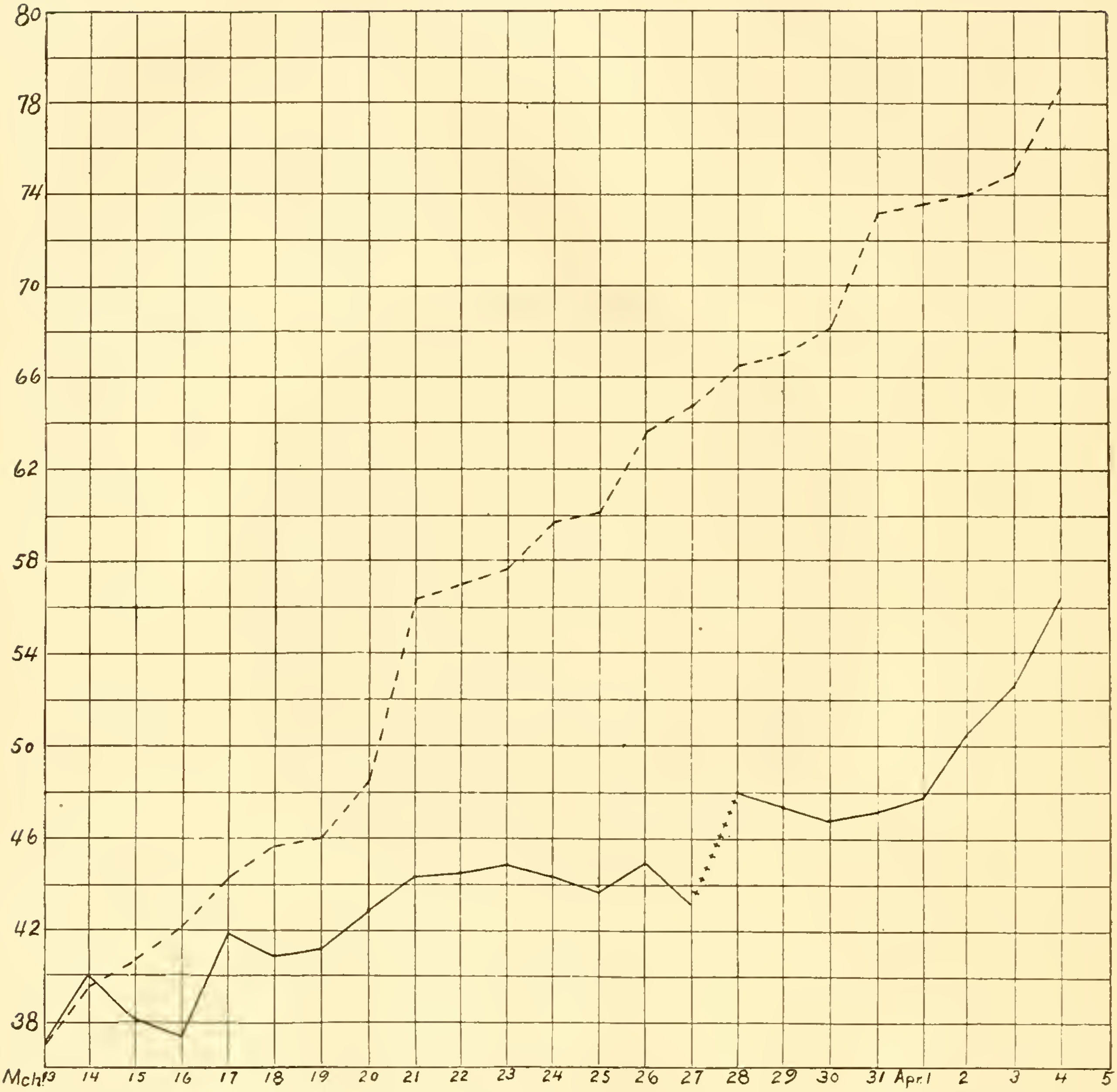
At the beginning of the test the chicks were divided into two lots of equal number and weight. One lot was marked by means of aniline dye (red) on head and wings—the other lot was left unmarked. The marked chicks were selected as the lot for test while the unmarked were kept as the normal or control chicks.

As previously stated both lots fed from the same hopper at all times but in addition to this vitamine lacking food the controls were allowed to partake once a day of foods containing vitamines; such food was usually a well known commercial "starting food," although frequently they were given lettuce, milk, apple, etc. The chart presenting the growth curves of the two lots strikingly shows the immediate differences that were

Typical appearance of the control chicks (left) and of those fed on food low in vitamine (right). Photograph taken April 4th, subsequent to replacing vitamines in food.

obtained in the daily average weight of the chicks (the graph does not show the weights for the first two days—which were almost identical).

One striking feature of the two growth curves is that when the normal chicks gained rapidly (as on March 19, 20, 21) the test chicks likewise show a definite increase, while when the normals' rate of growth slowed down (as on March 22 to 25) the test group failed to gain or even lost weight. The causes of these variations of growth in the controls are yet to be determined.



Curves showing the average daily weight per chick in grammes. Broken line, control chicks. Solid line, chicks fed a diet low in vitamines.

No deaths occurred in the normal group while 33% of the test chicks died. The apparent rapid rise in the curve on March 28th is due to the death of the smallest and feeblest chick which of course resulted in the rise of the average weight of the lot. A second chick died on March 31st and the remainder were in such condition that it was deemed advisable to prevent death if possible by feeding food containing vitamines. Incidentally it is worthy of note that the chicks die very promptly after the appearance of the symptoms of vitamine deficiency, such as the semi-paralysis, refusal to eat, progressive loss of weight, etc. By partially forced feeding the chicks were given small amounts of scraped apple, milk, lettuce, etc.—the result is clearly shown in the graph—April 1st to 4th—the growth rate actually exceeding that of the controls, although the amount of added nutritive material could not have been responsible, being entirely too small in amount. With the addition of the vitamines to the diet the test chicks at once began to eat larger amounts of the hopper feed than previously, the droopy appearance disappeared and they gave the appearance of merely undersized or stunted chicks.

On April 4th the use of the vitamine containing food was again discontinued—the result of further experimentation is yet to be determined. While it is recognized that no new results have been obtained by the use of the chicks it was thought that the very satisfactory demonstration secured was worthy of note at this time, since they apparently lend themselves so happily to laboratory experiment with a minimum of expense and trouble in their care.

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