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SMITHSONIAN INSTITUTION WASHINGTON 1846

SMITHSONIAN

MISCELLANEOUS COLLECTIONS

VOL. 76

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

(PUBLICATION 2822)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
1925

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

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CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

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BY
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(PUBLICATION 2715)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
JUNE 2, 1923

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SOME PRACTICAL ASPECTS OF FUEL ECONOMY

By CARL W. MITMAN

DIVISIONS OF MINERAL AND MECHANICAL TECHNOLOGY
UNITED STATES NATIONAL MUSEUM

Some ten years ago a large manufacturer in New England was approached with a proposal for materially bettering his fuel practice. The proposal was rejected on the grounds that coal represented less than 10 per cent of the cost of production, that a 10 per cent saving on this meant a saving of less than 1 per cent on the whole operation, and that economies of far greater consequence had prior claims to attention—in short, that the power plant was the least source of worry. Since then, however, this particular plant, in search of relief from its coal troubles, installed an oil burning equipment only to get caught in the rise of fuel oil prices and revert to coal, and on at least one occasion has been entirely shut down for lack of fuel.

The case is fairly typical and serves to bring out two points of fundamental importance: (1) That the fuel question has grown to be of major significance and (2) that its growth has been so rapid—largely within the last decade—that there scarcely has been time to work out the answer in standard form available to the average user. Thus, while consumers in general have come to appreciate these changing conditions to a greater or less degree, they have not been uniformly in a position to cope with them.

Power plant operations large enough to have the benefit of their own expert advice are able to work out the answer to their particular problems and are reasonably up to date in the way of equipment and operation. The average consumer, however, having no expert advice to bring to bear upon his problem, is dependent upon established practice, and in the absence of standards is still operating in the dark. The object of this writing is to bring out to what extent the average consumer may reasonably expect to profit from available data.

THE FURNACE A CHEMICAL PLANT

Combustion is a chemical reaction and a furnace is in reality a chemical plant manufacturing heat units. As such, the furnace operation falls into the same category with any other chemical process which, to be effectively operated, is at all times concerned with three important factors:

(1) The use of proper ingredients,

(2) In the proper proportions,

(3) Under the proper conditions.

By this is meant using the right coal under adequate furnace control and with the proper design of furnace installation. More specifically, the three issues involve: (1) The quality of coal, (2) furnace control, and (3) furnace installation, and will be taken up for discussion under these three general headings, but in reverse order.

FURNACE INSTALLATION

The manufacture of furnaces and boilers is a major industry in itself, composed of large organizations engaged in active competition and each having its own corps of highly trained experts. Exhaustive studies of combustion and heat absorption have been made not only under research conditions but under operating conditions as well. As a result, furnace and boiler designs have been developed which may be taken as embodying the best principles and suited to all ordinary requirements. This being the case, in the matter of furnace installation the consumer need scarcely concern himself beyond determining whether it is of standard design, reasonably up to date, and reasonably in keeping with the requirement.

FURNACE CONTROL

To appreciate the need for furnace control it is necessary to understand something of what takes place within the furnace. Reference has already been made to the combustion of coal as being a chemical reaction. Precisely speaking, it includes a number of reactions, involving the several ingredients composing coal, but inasmuch as carbon is the major ingredient, in the interest of simplicity, attention will be confined to its activity within the furnace.

When carbon burns it unites with the oxygen of the air in two ways. Expressed chemically, these are

$$C + O_2 = CO_2$$

and

$$2C + O_2 = 2CO$$

which means, taking into account the relative weights of the ingredients involved, that in the first reaction,

(1) 12 parts carbon + 32 parts oxygen = 44 parts carbon dioxide gas (a ratio of 1 carbon to 2.7 oxygen),

and in the second,

(2) 12 parts carbon + 16 parts oxygen = 28 parts carbon monoxide gas (a ratio of 1 carbon to 1.3 oxygen).

Chemical science has established the fact that the relationships expressed in reactions (1) and (2) are invariably fixed; for instance, that 12 parts of carbon requires exactly 32 parts of oxygen, forming exactly 44 parts carbon dioxide gas. Furthermore, the heat evolved in these combinations is a constant quantity. The heat evolved in reaction (1) is, however, over three times greater in amount that that evolved in reaction (2) for the reason that the former is the result of complete combustion. As a matter of fact, the carbon monoxide gas formed in reaction (2) can be ignited in the presence of air, and in the process of its combustion is converted to carbon dioxide. The heat released by this reaction added to that of reaction (2) will be equal to that released by the complete burning of carbon to carbon dioxide, as shown in reaction (1). Unburned and allowed to escape up the chimney, it means just so much coal (about two-thirds) wasted, or a 450 B. t. u. extraction from a 1350 B. t. u. coal. Yet it is not at all uncommon for a consumer to haggle over a variation of 50 heat units in the coal furnished him without giving the least heed to what is going up the stack.

Let us consider the matter of fixed relationships of ingredients a little further. If instead of supplying the exact amount of oxygen as called for in reaction (1), more is supplied, then, on the basis of chemical law,

(3) 12 parts carbon + 50 parts oxygen = 44 parts carbon dioxide gas + 18 parts uncombined oxygen (a ratio of 1 carbon to 4.2 oxygen),

while if less oxygen is supplied than theoretically required, the reaction would be

(4) 12 parts carbon + 20 parts oxygen = 8 parts carbon dioxide gas + 24 parts carbon monoxide gas (a ratio of 1 carbon to 1.8 oxygen).

Comparing reaction (3) with reaction (1) it will be noted that while the carbon consumed, and hence the heat generated, remains the same, the resultant gases have been materially increased in volume. When we consider further that the addition of 18 parts of oxygen, since it is introduced in the form of air, carries with it another 72 parts of nitrogen, the increase in volume is seen to be decidedly significant. One result is to lower the working temperature within the furnace precisely as the introduction of cool air into a room lowers the room temperature. Another ill effect is that since the flue gases carry off heat, any material increase in the volume of flue gases gives a correspondingly significant increase in the heat thus escaping.

Analyzing the results in reaction (4), it develops that only one-fourth of the carbon has been fully burned, the other three-fourths being two-thirds wasted; in other words, there has been only a 50 per cent extraction of heat units.

In short, adequacy of results is to be attained only as the requirements of exact chemical laws are met with exactitude. Deviations resulting in as much as 50 per cent loss in efficiency may easily go unnoticed in the absence of any definite check in the way of chemical control. As a matter of fact, it is not too much to say that modern industry is built around chemical control, and it is a striking fact that the one chemical process involving, in the aggregate, the largest capital outlay remains to-day largely subject to rule of thumb methods.

Domestic Application

The principles underlying effective combustion apply to the household furnace and to the power house installation alike. There is this difference however: In the former the furnace receives only casual attention and that of a perfunctory, inexpert nature, while the latter is being constantly ministered to by specially trained attendants. Accordingly, the smaller installations are subject to a handicap which prevents any rigorous application of chemical control, but this does not mean that an intelligent application of the general principles may not be made productive of significant results, especially in view of the present high fuel costs. It is not at all uncommon to encounter one consumer burning twelve or fourteen tons of coal while another operating under essentially similar conditions gets by with six or eight tons. Discrepancies such as these indicate conclusively the extent to which irregularities in practice may lead to readily preventable losses.

The general principles of effective combustion in substance boil down to having the furnace in good working order; exercising effective draft control; and using the coal best suited to the requirement. The defect most commonly encountered in the upkeep of the furnace itself is that of dirty flues. A one-eighth inch coating of soot provides an insulation which will cut the absorptive power over 25 per cent. The flues should be cleaned in the case of anthracite at least every few weeks and in the case of bituminous coal practically every day. Other defective developments commonly met with are in the form of leaky settings, cracks, warped castings, and the like. These, however, communicate their ill effects chiefly in the matter of draft control and may therefore be considered under that head.

In this latter connection, two general deductions are to be derived from what has been said in the preceding pages. First, that air entering the furnace above the fuel bed is objectionable in that it serves to lower the temperature within precisely as the influx of cold air lowers a room temperature. Second, an undue amount of air beyond that required for combustion, even when fed through the fuel bed, is open to the same objection. Accordingly, the common practice of opening the coaling door or even the slide in the door to check the fire is, in general, bad and should be resorted to only when absolutely necessary; similarly, holes or cracks admitting air above the fuel bed should be sealed as soon as they develop.

As too much air passing through the fuel bed has the same general effect as air fed over the bed, it follows that the further practice commonly met with of opening the ash pit door to obtain full draft is scarcely less objectionable than opening the coaling door, and leaky settings, cracks, etc., leading into the ash pit, in their general effect, are not unlike similar defects in the combustion chamber. So far as possible, the control over the furnace should be accomplished with the check damper, supplemented by the opening of the ash pit damper only to a sufficient degree and for a sufficient time to stimulate combustion. In this way excess air with its consequent cooling effect is cut to a minimum and the course of the gases is retarded, giving the maximum opportunity for the heat to be absorbed. One of the commonest practices met with combines about everything that has been pointed out as objectionable. This is the practice of banking the furnace at night leaving the coaling door open, to be followed in the early morning by opening up everything down below. This means the complete loss of the heat generated by combustion during the night followed by the cooling effect of excess draft throughout at least the early part of the day.

The value of having a coal uniformly suited to the requirement will be discussed in some detail later. It may be well here, however, to touch briefly on the important bearing that the size of coal exerts. The case comes to mind of a householder accustomed to using nut coal but forced under the stress of shortage to burn egg. His coal requirement became so excessive as to prompt investigation. This revealed that to start with, he used the same draft in the case of egg as with nut, but, failing to obtain the requisite heat, he opened the draft still further. This failed to help matters so he ended by keeping all drafts wide open and reconciled himself to the thought that the coal was deficient in heating value. It need scarcely be pointed out that the trouble lay in the fact that the larger size of coal gave free passage to the cold air which kept down the temperature in the combustion chamber and caused the hot gaseous products of combustion to pass directly into the chimney.

What has been said in the foregoing paragraphs relative to the domestic furnace operation applies directly to the use of anthracite coal and along with it the use of coke, its artificial equivalent, which has already made a considerable place for itself and is due for further extension. In using bituminous coal the slide in the coaling door should be left open to provide air for burning the volatile matter and closed immediately thereafter. A further difference of treatment desirable in the case of bituminous is that of firing on one-half of the fuel bed at a time, so as to always maintain a live combustion surface necessary to ignite the volatile matter. Adherence to this special procedure may be made to yield results for low volatile bituminous coals comparable to the use of anthracite, in the matter of smoke.

Industrial Application

As coal consumption reaches the stage of tons per day, the attention paid to the furnace becomes practically continuous so that any apparatus which can indicate or guide the operator in the control of the process of combustion can be effectively utilized. In this connection, a report of the United States Fuel Administration, covering the period from September 1, 1917, to March 1, 1919, contains the following passage:

> The average steam user in the whole United States knows but very little in detail about the operations of his steam plant or its economic possibilities. This has been largely due to the fact that coal has been cheap and in great quantity, and usually this department has been a small one compared to others. They are beginning to see, however, that a dollar saved in this department is worth as much as a dollar saved in any other, and we believe that in the near future the power department of the average manufacturing establishment will be given the same attention as any other department. The questionnaires returned to this office show that *ninety-five per cent* of the steam users have but the *faintest idea of their actual steam* costs, and these plants, as a general thing,

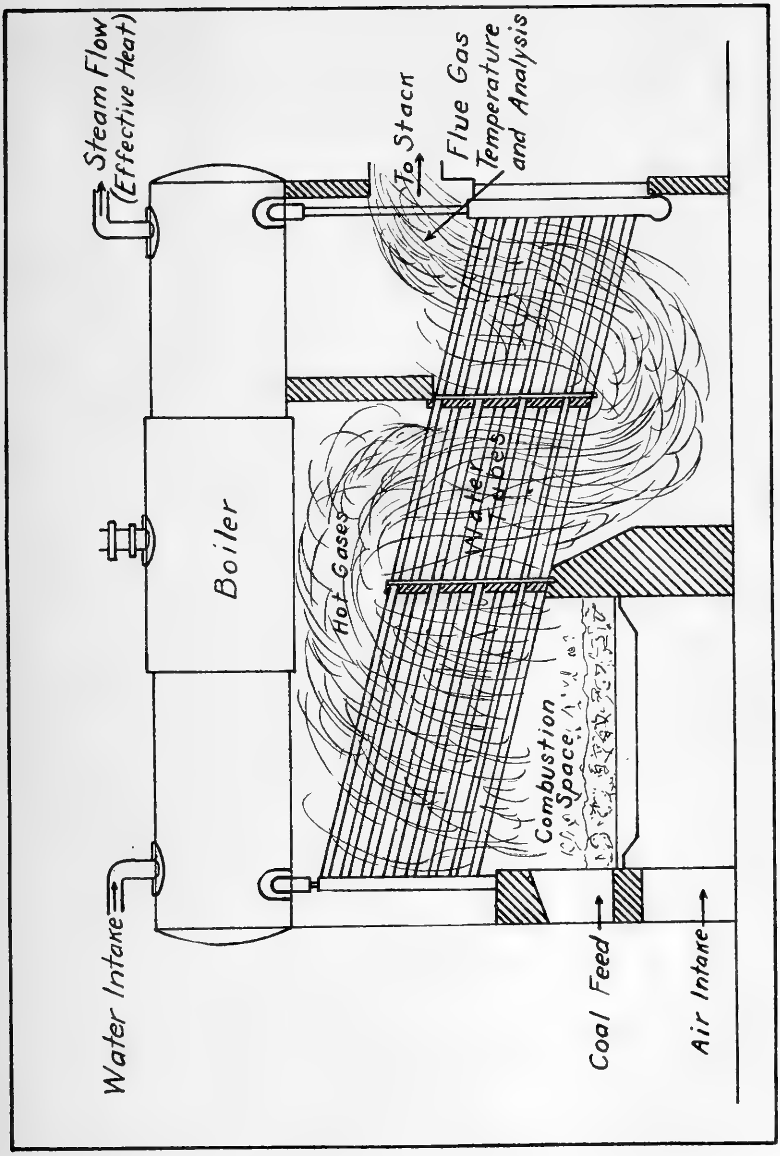

Fig. 1.—Working Principles of the Ordinary Industrial Furnace.

are still *run under the realm of guess-work.* Even some of the larger plants that are well equipped with various instruments to determine the efficiency of their plants and their unit cost of steam are operated with such an inferior class of help and with no intelligent supervision that these advantages are entirely lost.

Page 7 gives a graphic representation of the combustion reactions applied to industrial furnace practice. The coal fired on the grate plus air in the form of draft yields carbon dioxide in the form of waste gas plus or minus free air or free carbon monoxide gas, depending upon how the ideal reaction (1) has been approached. It will be noticed that the hot gases from combustion are forced to take a roundabout course on their way to the stack by the introduction of a series of baffles. This is to give the maximum opportunity for the boiler tubes to absorb the heat. In spite of this, the gases are still hot as they enter the chimney which means that they carry away a very appreciable amount of heat. Too much air fed in as draft results in an unnecessary volume of gases and a correspondingly preventable loss of heat. Insufficient air affords insufficient oxygen, resulting in incomplete combustion forming carbon monoxide instead of dioxide and the carrying off of two-thirds of the heat units as lost potentiality.

Two general lines of procedure suggest themselves for subjecting the industrial furnace to chemical control, namely, measuring the raw materials, coal and air, and measuring the results. The first named is impractical, if for no other reason than that of the ever varying composition of the coal, as will be discussed more in detail later. The second line of procedure, that of measuring the results, may seem, offhand, open to the objection of locking the door, as it were, after the horse is stolen. Given an indication of satisfactory versus unsatisfactory results, however, we are in a position to gage our procedure accordingly. This brings to mind the relationship already brought out, to the effect that the best results are, in general, attendant on the highest percentage of carbon dioxide in the flue gases, and points at once to the importance of flue gas analysis as a medium of control. Along with this, the importance of steam flow measurement is self-evident inasmuch as steam is what is most desired. These two together afford a check against one another in the determination of results and the fixing upon the procedure best calculated to bring them about. All that now remains is to interpret these results in terms of the conditions existing in the furnace and provide a means for maintaining those conditions uniformly. Thus with the co-ordination of three sets of records we are in a position to subject the whole operation to definite chemical control. These three will now be taken up in turn for discussion.

Steam Flow Measurement

Experience reveals the surprising fact that the average operator, more particularly the smaller operator, has not the remotest conception as to how much steam he is securing, in other words, whether he is operating on an efficient basis of seven or eight pounds of steam per pound of coal or whether he is getting only four or five pounds. Accordingly, taken by itself a steam flow indicator is a first requisite to enable the operator to be cognizant of conditions and the possible room for improvement. Its further function as an adjunct to the fitting control of furnace practice has already been brought out.

The steam flow meter is applied to the steam outlet of the boiler and in its simpler form will indicate on its dial the momentary output of steam. There are several types of flow meters made, all of which, however, are designed fundamentally on the Pitot tube or the Venturi tube principle. Whatever the type, the meter is installed in the steam line and the steam in passing through the mechanism produces a differential pressure which is proportional to the square of its velocity or rate of flow. Any change in pressure actuates the indicating hand on the meter dial, the readings on which may be in pounds per hour or in horsepower.

Flue Gas Analysis

Thanks to the efforts of scientists, the chemistry of gases, and particularly their analysis, has been resolved into quite a simple procedure. There are several ways in which gases may be analyzed, depending upon one or another of the properties of the individual compounds composing them as, for instance, the differences in refractive power of the constituents, and again, the power of certain chemical reagents to select and absorb one of the several compounds. A familiar application of this latter principle is the gas mask used during the war, in which a certain reagent is used to absorb the poisonous constituent of the war gas before the air containing it is breathed into the lungs. It is this same principle that is most generally used in the analysis of flue gases, and while the several types of apparatus used to make analyses by this method may vary as to detail, they are simply modifications of the apparatus devised about 50 years ago by the French scientist, Orsat.

We have seen earlier that the significant gases which may pass up the stack of a furnace are carbon dioxide, oxygen, and carbon monoxide. To analyze such a gaseous mixture by the Orsat method means simply to bring about the absorption of each one of the constituents and determine by the resultant changes in volume the percentage composition. A solution of caustic potash will absorb carbon dioxide but neither oxygen nor carbon monoxide; further, a solution of pyrogallic acid and caustic potash will absorb oxygen; and lastly, an ammoniacal solution of cuprous chloride will absorb carbon monoxide. These are the reagents used. Figure 2 shows a simple form of Orsat apparatus. The graduated bulb on the right measures a unit quantity of the flue gas to be analyzed; the three bulbs to the left contain the several absorption reagents; that one immediately adjoining the graduated bulb absorbs carbon dioxide; the next to the left absorbs oxygen; and the last absorbs carbon monoxide. In operation a measured quantity of flue gas is admitted into the graduated bulb, and by means of simple valves and the leveling bottle shown, the gas is forced into the carbon dioxide absorption bulb; here it is allowed to remain for a time, during which the carbon dioxide is absorbed by the caustic potash, after which the gas is drawn back to the graduated bulb and the difference in volume resulting represents the percentage of carbon dioxide originally present. In a similar way the percentage of oxygen is determined after the carbon dioxide has been removed from the gas, by absorption in the second bulb. Finally, after the removal of both the carbon dioxide and the oxygen, the percentage of carbon monoxide is determined by absorption of the remaining gas in the third bulb.

With a hand analyzer such as shown, the percentage of carbon dioxide may be determined in the short space of a minute, but to determine oxygen and carbon monoxide in addition to carbon dioxide, will require about 15 minutes. We have seen earlier, however, that a knowledge of the percentage of carbon dioxide alone is extremely helpful in bringing about a good furnace practice and only in the exceptional case is it necessary to determine oxygen and carbon monoxide with each analysis made.

Referring back to the furnace reactions on page 3, it will be noted that the best practice is that which gives the lowest percentage of oxygen and free carbon monoxide gas or, in other words, that which gives the highest percentage of carbon dioxide gas. The reaction (1), resulting in complete combustion, theoretically yields about 20 per cent carbon dioxide, but in furnace practice the reaction is never a complete one and as a result a certain percentage of free oxygen or free carbon monoxide may be present. This means that

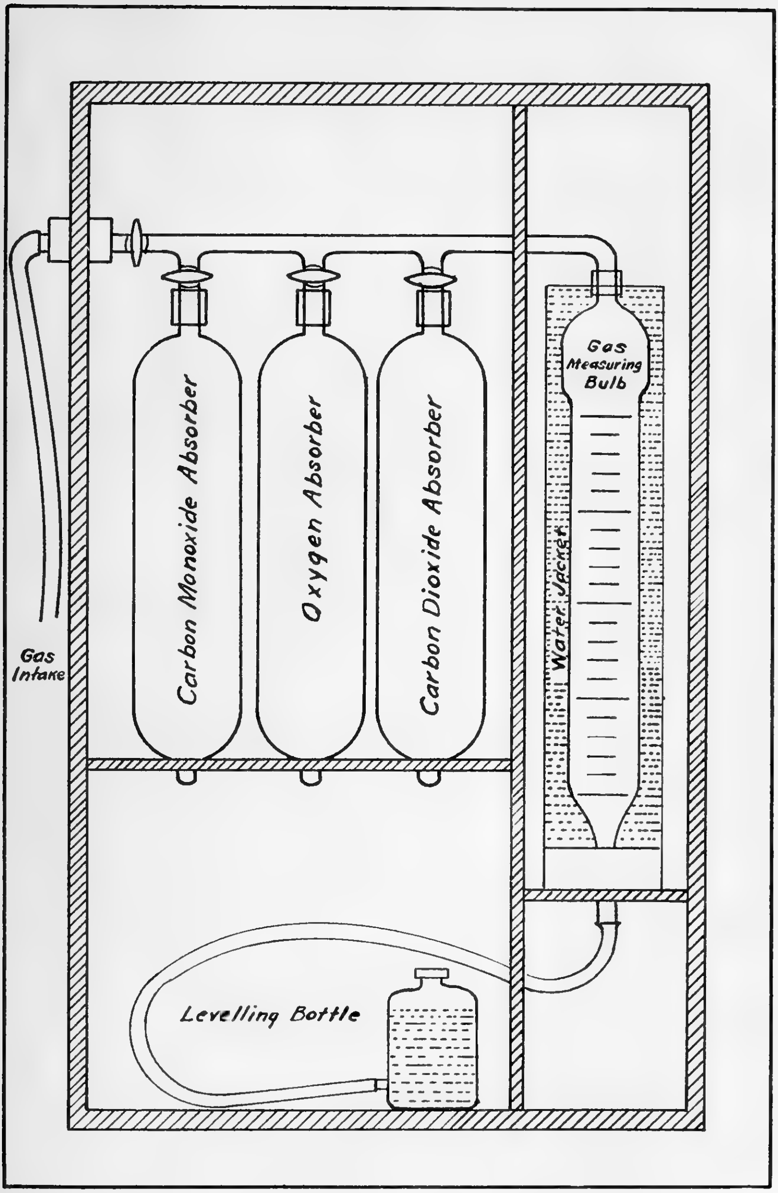

FIG. 2.—Simple Form of Orsat Gas Analyzer.

carbon dioxide never reaches 20 per cent in practice, the best average being around 15 per cent. Leaky furnace settings and other conditions may very materially affect the best practical figure for carbon dioxide, and accordingly that which proves to be the best for one furnace may not be the best for another. Each furnace operation, therefore, becomes to a more or less degree a case unto itself. A number of tests of furnaces in operation have shown an average yield of between 5 and 7 per cent carbon dioxide, which means that as nearly as generalities may be drawn, there is an undue volume of flue gas and a corresponding loss of heat. Satisfactory results, however, are measured in terms of steam produced per pound of fuel burned, so that for a given case the best practice is to secure that percentage of carbon dioxide which will produce the maximum of steam. Right here is to be seen the need of co-ordinating between a carbon dioxide indicator and a steam flow gage.

Air Control

We have observed how the analysis of flue gases is an index of the extent to which proper combustion is effected, but it must be apparent also that these analyses do not give any indication as to the conditions which produced them. For example, a furnace may be operating with a good carbon dioxide yield and steam output when suddenly the flue gas analyzer indicates a falling off of the former and the steam output drops. It is decided that too much air is entering the furnace and the damper is adjusted to cut down the draft, but the steam output continues to fall. Again the damper is adjusted, this time to increase the draft, but still no improvement is observed. The facts in the matter are that one or more of a number of things may have occurred such as the formation of clinkers, holes burned in the baffles, holes in the fuel bed, or an opening in the setting, any one of which may have caused the trouble but which damper manipulations alone could not correct and which are not indicated by the gas analyzer.

There is need, therefore, for an indicator of furnace conditions which is furnished by the draft gage. Its method of operation and the interpretation of its readings, however, require a little explanation.

We are all familiar, in a general way, with chimney drafts. The pull of this draft creates a partial vacuum within the furnace so that a pressure exists there which is less than that outside. To equalize this pressure difference, air enters the furnace and is sucked up through the fuel bed, passes through the combustion chamber and around the boiler heating surfaces and so on out of the stack, but the resistances met with in its flow prevent complete equalization, so that a difference in pressure, or differential pressure, as it is called, always exists and in amounts proportional to the resistances. Any untoward condition, however, taking place within the furnace, such as a hole in the fuel bed, alters the resistance to the flow of air which, in turn, causes the differential pressure to change. In other words, the pressure differential affords a measure of the air feed and an indication of furnace conditions as well. Such is the draft gage, for it is a pressure recording instrument made especially to indicate the pressure difference between the outside and inside of a furnace.

When furnace conditions are right and the percentage of carbon dioxide is such as to give the maximum steam output, a certain amount of resistance exists in the furnace, represented by a certain pressure difference indicated on the draft gage. As long as this condition exists, there is an assurance of the existence of a uniform pressure, but if some change takes place within the furnace which alters the resistances, permitting an increase or decrease in air supply, it is immediately indicated by a change in pressure. In many instances the condition can be corrected in time to prevent any appreciable change in steam output and before its effect is indicated in the quality of the flue gases. In other words, the draft gage intelligently used is the mainstay of an established furnace practice.

Flue Gas Temperature

Experience in chemical control has demonstrated that success is attained in the degree to which each and every operation involved is under observation. Thus, in the case in hand, the objective is the most economic production of heat for the steam output required, and while there is a surety that with the proper co-ordination of flue gas analyses and steam output maintained by a draft gage the objective is being attained, still a further check such as the temperature of the gases as they leave the boiler heating surfaces, will, in a measure, constitute more or less proof, inasmuch as the generally accepted permissible temperature of the gases as they go up the stack is around 500 degrees Fahrenheit. Obviously, therefore, the use of a thermometer or some other temperature recording device will be beneficial. It is conceivable, too, that even though proper combustion is taking place and sufficient heat is produced, a condition may arise whereby the heat so produced is not being absorbed by the boiler heating surfaces or that the latter are deprived of sufficient opportunity to absorb the heat, so that excess heat would pass up the stack. Thus, a temperature recording device may be an indicator both of the heat producing and heat absorbing functions of the furnace.

Limitations

Recording devices whatever their nature do not in themselves provide the requisite control of furnace operations but simply substitute exact data for guess-work to guide the operator. Accordingly, the installation of any system of control will be effective only in proportion as the data are intelligently interpreted and applied.

The case comes to mind of a large central heating plant with a wide-awake chief engineer, cognizant of fuel wastes and means for their elimination, who equipped each one of his mechanically stokered boilers with draft gages, a permanently installed flue gas analyzer and a recording thermometer, and with this apparatus established his standards. His firemen were apparently brought to the point of seeing the advantages to themselves of making use of the equipment and were fully instructed as to the meaning of it all. In spite of this, on several occasions the engineer has come upon a fireman closing a hole in the fuel bed by firing coal through the two-foot cleaning door on the side of the setting, thus allowing volumes more of air to enter the furnace than could possibly enter even through the hole in the fuel bed, and in spite of the warnings, the engineer to-day is not sure but that, when the occasion arises, the firemen will repeat the same operation. In short, the human factor must be considered.

There are two general types of control apparatus, namely, indicating and recording. The former type is of value only as providing a guide to the fireman and is no safeguard against his failings. The recording type, however, in furnishing an uninterrupted register, serves not only as a guide to the fireman but also as a record of efficiencies for the operator.

Costs

The simple form of Orsat gas analyzer, designed along the lines of the sketch shown on page 11, may be purchased for around 40 dollars. It is a portable outfit and properly used, can make a carbon dioxide analysis in about a minute's time. There is also the fixed installation equipped with gas collector ready at any time to make analyses. Another device is in the form of a continuous indicator with or without the further refinement of a permanent record.

A steam flow meter in its simplest form represents an outlay of approximately 175 dollars and a draft gage by itself around 15 dollars. A compound recording device, registering on the same chart and at corresponding moments both flue gas and draft conditions, is to be had as standard equipment. A still more comprehensive equipment indicates the fire-box draft and the steam flow, and registers and records the steam flow, air flow and flue gas temperature all on one chart. This latter order of equipment represents an outlay of approximately 700 dollars.

The very nature of control equipment presupposes some intelligent attention to maintain it for continuous operation. Fresh reagents must periodically replace those being used in an analyzer and again a supply of charts for the recording types of instruments must be had. It is conservatively estimated, however, that a direct recording flue gas analyzer, for example, can be kept in continuous operation at a cost of about 30 dollars annually.

Advantages

Fuel economy is dependent upon two factors, adequacy of installation and boiler room efficiency. Both are variable factors and, as a natural consequence, the data assembled as to furnace practices show an extraordinary range of efficiencies. One operation is getting a yield of from seven to eight pounds of steam for each pound of coal burned, while near by another of exactly the same order is getting but three or four pounds. In the face of these varying efficiencies, no exact statement generally applicable can be made as to the possibility of savings through subjecting an operation to chemical control. Instances are on record of cutting fuel costs as much as 50 per cent, which probably represent the upper limit of advantage to be gained. On the other hand, it is safe to say that no rule of thumb procedure can approximate the exactitude of chemical law within 10 per cent; in other words, a saving of 10 per cent in fuel costs may be counted upon with assurance.

The direct saving in dollars and cents on the fuel bill is not the only line of advantage to be gathered. The furnace room is the energizing force back of the plant operation, whatever its nature, and dependability for meeting the requirements as they arise is the prime requisite. A sudden demand for steam met by opening up a draft so wide as to feed excess air which results in cooling the boiler tubes and actually lowering the steam flow, does more than waste fuel because it impairs efficiencies throughout the plant. Thus, losses perhaps many times over that in fuel may be entailed, all of which would be prevented or even anticipated by furnace control.

Still another aspect of the situation merits consideration among the advantages to be gained. Cost accounting has come to be regarded as a necessary adjunct to effective administration. It has an importance beyond that of any direct cutting of costs in that it affords protection against any unjustifiable developments which might otherwise go unnoticed. Furnace control data, more particularly those afforded by the recording type of instrument, furnish what amounts to a system of cost accounting and have precisely the same advantage as a measure of protection that the more orthodox form offers.

QUALITY OF COAL

There are two general classes of coal used, anthracite and bituminous. Adding the adjectives good and poor, for the majority of users both large and small, this just about sums up the actual discriminatory knowledge of the subject.

The administrative head of a nationally known organization, experiencing difficulty in obtaining anthracite, raised the question of shifting over to bituminous coal, but was met with the reply that the power requirements were of an order that could be met satisfactorily only by anthracite. As the difficulty in securing anthracite increased, he became more persistently inquisitive until, at length, word was passed to him from a subordinate in the power house that the engineer in charge was an "anthracite engineer," and that bituminous coal of proper specification might be made to serve the purpose as well, if not better. The change was finally ordered and has been in effect ever since, with the result that bituminous coal has shown itself preferable in every respect.

The responsible head of a locally prominent plant, approached on the question of fuel economy, professed to regard it as something to which he had given careful consideration in the running of his plant, and stated that all his coal was purchased on a heat unit basis. Questioned further, he disclaimed any particular interest in any of the other characteristics of coal for the reason that heat units were what he wanted and, accordingly, heat units were what he was interested in buying. Examination of his furnace operation revealed around 40 per cent of preventable losses.

Still another executive of an industrial operation, after raising the question as to the relative merits of New River coal versus that bearing a well-known trade name, himself proceeded to answer the question with the statement that in his experience the trade name coal was vastly superior to New River. It happens that the trade name, while originally employed to designate a coal of a certain mine, is no longer applied to the product even from a fixed district and, as a matter of fact, the coal of this name has been coming for the past few years from the New River District.

Instances of this order can be added to more or less indefinitely and serve to show the degree to which what passes for knowledge is actually built up of notion. In times past coal has been so cheap and available that there has been little occasion to give it any particular consideration, which doubtless explains to a considerable degree the lack of genuine discriminatory knowledge of the subject. The system of marketing coal, however, has contributed largely, perhaps even to being the factor generally responsible.

The mining and marketing, more particularly the retail marketing of coal, are two totally distinct industries. The mine operator is utterly out of touch with retail yard operations and vice versa. Moreover there is no immediate connection, the two being separated by an intervening middle interest. The reason for the middle or so-called jobbing interest is to be found, largely at least, in the ever fluctuating price of coal at the mines, and the reason for this, in turn, lies in the vast extent of the bituminous coal lands coupled with the wide variation in producing costs. Given under production, the mine price of coal takes an upward turn and as it mounts, mines hitherto shut down owing to prohibitive mining costs, are able to open up. This process of increasing price and increasing production continues until over production is reached, when a decline in price sets in which forces the little, high cost operators to shut down. This continues in its turn until under production is reached, starting the cycle over again. In the face of this condition at the source, any fixed contract price, whatever the figure, is bound as time passes to reflect to the disadvantage of one party or the other, and each is pretty apt to find the means for avoiding the contract.

The coal retailer generally buys through several jobbers, each of whom handles the product from several mine operations and, as a consequence, the retail yard commonly receives coal, even of a given type, from a number of mines. At best, there is a considerable range that requires separation when we consider the radically distinct types of coal and the various sizes, and when we add the varying products from a number of mines, the range precludes the possibility of having a complete separation even in the best equipped yard.

Disregarding this unreasonable multiplicity of qualities, grades and sizes, the average retail yard is, to say the least, poorly equipped to maintain uniformity in the quality of the coal it distributes. It is hardly more than a railway trestle dump and is commonly located toward the heart of the city where the growth of municipal fixtures has prevented expansion. The general result is a series of trestle dumps, too few to admit of adequate grading of coal and too low to the ground to admit pocket storage and loading, with the net consequence that the coal of a given type, even though coming from various mines, is dumped together on the ground.

Samples of bituminous coal gathered from the yards in almost any city will show an ash content ranging from 2 to 20 per cent; sulphur from less than one-half of 1 per cent to upward of 4 per cent; from high fusible ash to low fusible ash; from 15 per cent volatile matter to 40 per cent; and from almost wholly slack to 70 per cent lump. The group characteristics, volatile matter, ash, sulphur, etc., run more or less uniform for a given mine but vary for different mines even in a given district. Accordingly, the yard procedure just outlined results in the inability to maintain anything like uniform standards of quality. Furthermore the average consumer, in not being educated as to fixed standards, quite naturally lacks adequate discriminatory knowledge of the subject, which, however, has an important bearing on fuel economy.

Thus has come about a vicious circle in which the consuming interests, not having been educated up to require uniform standards, do not demand them, and the marketing interests, having no call for uniform standards, have taken no pains to supply them. This is an unfortunate situation for, as will readily be seen, it stands in the way of subjecting furnace practice to chemical control. One coal requires a thicker fuel bed, another a thinner bed; one requires a larger, and another a smaller combustion space; one requires a weaker and another a stronger draft, and so on. Fortunately there are evidences which point to the dawning of a new era in which standards of service will be developed in keeping with recognized standards of requirement. This will be speeded up or retarded just in proportion as the consumer learns the value of uniform standards.

The principles underlying combustion and the consequent advantages to be gained by chemical control are applicable all the way from the small household furnace to the largest of power installations. There is this general difference, however, that the latter is under continual observation, whereas the former receives but casual attention at intervals during the day and then, at best, of a perfunctory nature. Accordingly, the use of control instruments of the order mentioned for household furnace operations is of no advantage since these instruments are only indicators of conditions and guides to efficient combustion.

Instruments as a guide to chemical control become applicable as attention to furnace operations becomes more or less constant; in other words, as the consumption of coal reaches the stage of tons per day. One plant may feel justified in supplying draft gages only, while another may be able to provide a gas analyzer in addition, but just in proportion as a complete system of control is instituted there is the consequent assurance of securing definite economies. Irrespective of the actual savings to be effected, the application of chemical control by all consuming interests must bring about that discriminatory knowledge of the general subject which is now largely lacking. Once this is attained and standard practices are established, the consumer will be in a position to demand and receive uniformity and service of the marketing interests.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 76, NUMBER 2

HISTORY OF ELECTRIC LIGHT

BY

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(PUBLICATION 2717)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
AUGUST 15, 1923

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

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LIST OF ILLUSTRATIONS

Portion of the Electrical Exhibit in the United States National Museum.
Section devoted to the historical development of the electric light and dynamo.

FOREWORD

In the year 1884 a Section of Transportation was organized in the United States National Museum for the purpose of preparing and assembling educational exhibits of a few objects of railroad machinery which had been obtained both from the Centennial Exhibition held in Philadelphia in 1876 and still earlier as incidentals to ethnological collections, and to secure other collections relating to the railway industry.

From this beginning the section was expanded to include the whole field of engineering and is designated at present as the Divisions of Mineral and Mechanical Technology. The growth and enlargement of the collections has been particularly marked in the fields of mining and mineral industries; mechanical engineering, especially pertaining to the steam engine, internal combustion engine and locomotive; naval architecture, and electrical engineering, particularly the development of the telegraph, telephone and the electric light.

In the acquisition of objects visualizing the history of electric light the Museum has been rather fortunate, particularly as regards the developments in the United States. Thus mention may be made of the original Patent Office models of the more important dynamos, arc lights and incandescent lights, together with original commercial apparatus after these models; a unit of the equipment used in the first commercially successful installation on land of an incandescent lighting system, presented by Joseph E. Hinds in whose engraving establishment in New York City the installation was made in 1881; and a large series of incandescent lights, mainly originals, visualizing chronologically the developments of the Edison light from its inception, presented at intervals since the year 1898 by the General Electric Company.

The object of all collections in the Divisions is to visualize broadly the steps by which advances have been made in each field of engineering; to show the layman the fundamental and general principles which are the basis for the developments; and to familiarize the engineer with branches of engineering other than his own. Normally when a subject is completely covered by a collection of objects, a paper is prepared and published describing the collection and the story it portrays. In the present instance, however, on account of the uncertainty of the time of completing the collection, if it is possible ever to bring this about, it was thought advisable to publish Mr. Schroeder's paper which draws upon the Museum collection as completely as possible.

Carl W. Mitman,
Curator, Divisions of Mineral and Mechanical Technology, U. S. National Museum.

CHRONOLOGY OF ELECTRIC LIGHT

1800—Allesandro Volta demonstrated his discovery that electricity can be generated by chemical means. The VOLT, the unit of electric pressure, is named in his honor for this discovery of the electric battery.

1802—Sir Humphry Davy demonstrated that electric current can heat carbon and strips of metal to incandescence and give light.

1809—Sir Humphry Davy demonstrated that current will give a brilliant flame between the ends of two carbon pencils which are first allowed to touch each other and then pulled apart. This light he called the " arc " on account of its arch shape.

1820—André Marie Ampère discovered that current flowing through a coiled wire gives it the properties of a magnet. The AMPERE, the unit of flow of electric current, is named in his honor for this discovery.

1825—Georg Simon Ohm discovered the relation between the voltage, ampereage and resistance in an electric circuit, which is called Ohm's Law. The OHM, the unit of electric resistance, is named in his honor for this discovery.

1831—Michael Faraday discovered that electricity can be generated by moving a wire in the neighborhood of a magnet, the principle of the dynamo.

1840—Sir William Robert Grove demonstrated his experimental incandescent lamp in which platinum is made incandescent by current flowing through it.

1841—Frederick De Moleyns obtained the first patent on an incandescent lamp. The burner was powdered charcoal operating in an exhausted glass globe.

1845—Thomas Wright obtained the first patent on an arc light.

1845—J. W. Starr invented an incandescent lamp consisting of a carbon pencil operating in the vacuum above a column of mercury.

1856—Joseph Lacassagne and Henry Thiers invented the " differential " method of control of the arc which was universally used twenty years later when the arc lamp was commercially established.

1862—The first commercial installation of an electric light. An arc light was put in a lighthouse in England.

1866—Sir Charles Wheatstone invented the "self-excited" dynamo, now universally used.

1872—Lodyguine invented an incandescent lamp having a graphite burner operating in nitrogen gas.

1876—Paul Jablochkoff invented the "electric candle," an arc light commercially used for lighting the boulevards in Paris.

1877-8—Arc light systems commercially established in the United States by William Wallace and Prof. Moses Farmer, Edward Weston, Charles F. Brush and Prof. Elihu Thomson and Edwin J. Houston.

1879—Thomas Alva Edison invented an incandescent lamp consisting of a high resistance carbon filament operating in a high vacuum maintained by an all glass globe. These principles are used in all incandescent lamps made to-day. He also invented a completely new system of distributing electricity at constant pressure, now universally used.

1882—Lucien Goulard and John D. Gibbs invented a series alternating current system of distributing electric current. This has not been commercially used.

1886—William Stanley invented a constant pressure alternating current system of distribution. This is universally used where current is to be distributed long distances.

1893—Louis B. Marks invented the enclosed carbon arc lamp.

1898—Bremer's invention of the flame arc lamp, having carbons impregnated with various salts, commercially established.

1900—Dr. Walther Nernst's invention of the Nernst lamp commercially established. The burner consisted of various oxides, such as zirconia, which operated in the open air.

1901—Dr. Peter Cooper Hewitt's invention of the mercury arc light commercially established.

1902—The magnetite arc lamp was developed by C. A. B. Halvorson, Jr. This has a new method of control of the arc. The negative electrode consists of a mixture of magnetite and other substances packed in an iron tube.

1904—D. McFarlan Moore's invention of the Moore vacuum tube light commercially established. This consisted of a long tube, made in lengths up to 200 feet, from which the air had been exhausted to about a thousandth of an atmosphere. High voltage current passing through this rarefied atmosphere caused it to glow. Rarefied carbon dioxide gas was later used.

1905—Dr. Auer von Welsbach's invention of the osmium incandescent lamp commercially established, but only on a small scale in Europe. The metal osmium, used for the filament which operated in vacuum, is rarer and more expensive than platinum.

1905—Dr. Willis R. Whitney's invention of the Gem incandescent lamp commercially established. The carbon filament had been heated to a very high temperature in an electric resistance furnace invented by him. The lamp was 25 per cent more efficient than the regular carbon lamp.

1906—Dr. Werner von Bolton's invention of the tantalum incandescent lamp commercially established.

1907—Alexander Just and Franz Hanaman's invention of the tungsten filament incandescent lamp commercially established.

1911—Dr. William D. Coolidge's invention of drawn tungsten wire commercially established.

1913—Dr. Irving Langmuir's invention of the gas-filled tungsten filament incandescent lamp commercially established.

HISTORY OF ELECTRIC LIGHT

By HENRY SCHROEDER,
HARRISON, NEW JERSEY.

EARLY RECORDS OF ELECTRICITY AND MAGNETISM

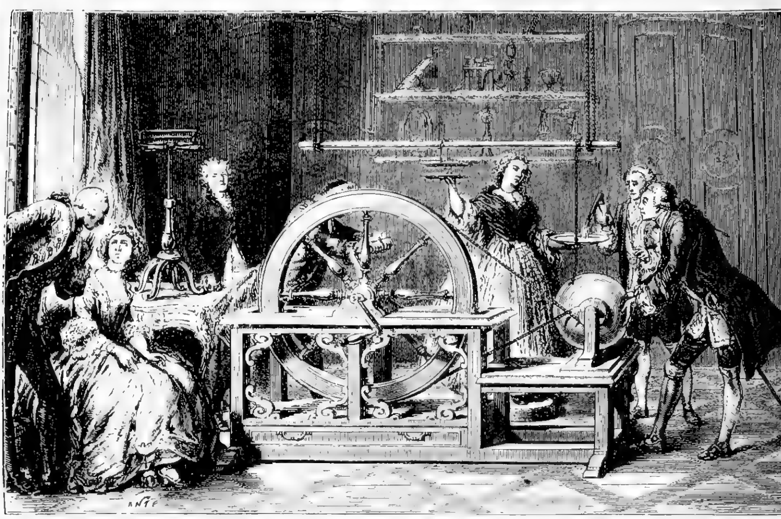
About twenty-five centuries ago, Thales, a Greek philosopher, recorded the fact that if amber is rubbed it will attract light objects. The Greeks called amber "elektron," from which we get the word "electricity." About two hundred and fifty years later, Aristotle, another Greek philosopher, mentioned that the lodestone would attract iron. Lodestone is an iron ore (Fe_3O_4), having magnetic qualities and is now called magnetite. The word "magnet" comes from the fact that the best specimens of lodestones came from Magnesia, a city in Asia Minor. Plutarch, a Greek biographer, wrote about 100 A. D., that iron is sometimes attracted and at other times repelled by a lodestone. This indicates that the piece of iron was magnetised by the lodestone.

In 1180, Alexander Neckham, an English Monk, described the compass, which probably had been invented by sailors of the northern countries of Europe, although its invention has been credited to the Chinese. Early compasses probably consisted of an iron needle, magnetised by a lodestone, mounted on a piece of wood floating in water. The word lodestone or "leading stone" comes from the fact that it would point towards the north if suspended like a compass.

William Gilbert, physician to Queen Elizabeth of England, wrote a book about the year 1600 giving all the information then known on the subject. He also described his experiments, showing, among other things, the existence of magnetic lines of force and of north and south poles in a magnet. Robert Norman had discovered a few years previously that a compass needle mounted on a horizontal axis would dip downward. Gilbert cut a large lodestone into a sphere, and observed that the needle did not dip at the equator of this sphere, the dip increasing to 90 degrees as the poles were approached. From this he deduced that the earth was a magnet with the magnetic north pole at the geographic north pole. It has since been determined that these two poles do not coincide. Gilbert suggested the use of the dipping needle to determine latitude. He also discovered that other substances, beside amber, would attract light objects if rubbed.

MACHINES GENERATING ELECTRICITY BY FRICTION

Otto Von Guericke was mayor of the city of Magdeburg as well as a philosopher. About 1650 he made a machine consisting of a ball of sulphur mounted on a shaft which could be rotated. Electricity was generated when the hand was pressed against the globe as it rotated. He also discovered that electricity could be conducted away from the globe by a chain and would appear at the other end of the chain. Von Guericke also invented the vacuum air pump. In 1709, Francis Hawksbee, an Englishman, made a similar machine, using a



Otto Von Guericke's Electric Machine, 1650.
A ball of sulphur was rotated, electricity being generated when it rubbed against the hand.

hollow glass globe which could be exhausted. The exhausted globe when rotated at high speed and rubbed by hand would produce a glowing light. This "electric light" as it was called, created great excitement when it was shown before the Royal Society, a gathering of scientists, in London.

Stephen Gray, twenty years later, showed the Royal Society that electricity could be conducted about a thousand feet by a hemp thread, supported by silk threads. If metal supports were used, this could not be done. Charles du Fay, a Frenchman, repeated Gray's experiments, and showed in 1733 that the substances which were insulators, and which Gilbert had discovered, would become electrified if rubbed. Those substances which Gilbert could not electrify were conductors of electricity.

THE LEYDEN JAR

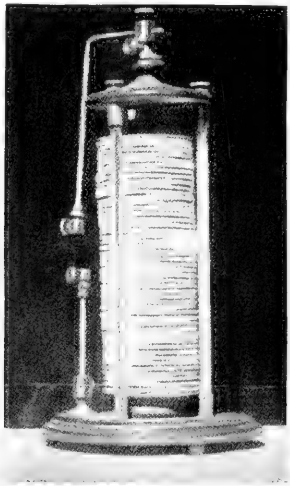
The thought came to Von Kleist, Bishop of Pomerania, Germany, about 1745, that electricity could be stored. The frictional machines generated so small an amount of electricity (though, as is now known, at a very high pressure—several thousand volts) that he thought he could increase the quantity by storing it. Knowing that glass was an insulator and water a conductor, he filled a glass bottle partly full of water with a nail in the cork to connect the machine with the water. Holding the bottle in one hand and turning the machine with the other for a few minutes, he then disconnected the bottle from the machine. When he touched the nail with his other hand he received a shock which nearly stunned him. This was called the Leyden jar, the forerunner of the present condenser. It received its name from the fact that its discovery was also made a short time after by experimenters in the University of Leyden. Further experiments showed that the hand holding the bottle was as essential as the water inside, so these were substituted by tin foil coatings inside and outside the bottle.

Benjamin Franklin, American statesman, scientist and printer, made numerous experiments with the Leyden jar. He connected several jars in parallel, as he called it, which gave a discharge strong enough to kill a turkey. He also connected the jars in series, or "in cascade" as he called it, thus establishing the principle of parallel and series connections. Noticing the similarity between the electric spark and lightning, Franklin in 1752, performed his famous kite experiment. Flying a kite in a thunderstorm, he drew electricity from the clouds to charge Leyden jars, which were later discharged, proving that lightning and electricity were the same. This led him to invent the lightning rod.

ELECTRICITY GENERATED BY CHEMICAL MEANS

Luigi Galvani was an Italian scientist. About 1785, so the story goes, his wife was in delicate health, and some frog legs were being skinned to make her a nourishing soup. An assistant holding the legs with a metal clamp and cutting the skin with a scalpel, happened to let the clamp and scalpel touch each other. To his amazement the frog legs twitched. Galvani repeated the experiment many times by touching the nerve with a metal rod and the muscle with a different metal rod and allowing the rods to touch, and propounded the theory of animal electricity in a paper he published in 1791.

Allesandro Volta, a professor of physics in the University of Pavia, Italy, read about Galvani's work and repeated his experiments. He found that the extent of the movement of the frog legs depended on the metals used for the rods, and thus believed that the electric charge was produced by the contact of dissimilar metals with the moisture in the muscles. To prove his point he made a pile of silver



VOLTAIC PILE, 1799.

Volta discovered that electricity could be generated by chemical means and made a pile of silver and zinc discs with cloths, wet with salt water, between them. This was the forerunner of the present-day dry battery. Photograph courtesy Prof. Chas. F. Chandler Museum, Columbia University, New York.

and zinc discs with cloths, wet with salt water, between them. This was in 1799, and he described his pile in March, 1800, in a letter to the Royal Society in London.

This was an epoch-making discovery as it was the forerunner of the present-day primary battery. Volta soon found that the generation of electricity became weaker as the cloths became dry, so to overcome this he made his "crown of cups." This consisted of a series of cups containing salt water in which strips of silver and zinc were dipped. Each strip of silver in one cup was connected to the zinc strip in the next cup, the end strips of silver and zinc being terminals of the battery. This was the first time that a continuous supply of electricity in reasonable quantities was made available, so the VOLT, the unit of electrical pressure was named in his honor. It was later shown that the chemical affinity of one of the metals in the liquid was converted into electric energy. The chemical action of Volta's battery is that the salt water attacks the zinc when the circuit is closed forming zinc chloride, caustic soda and hydrogen gas. The chemical equation is:

$$Zn + 2NaCl + 2H_2O = ZnCl_2 + 2NaOH + H_2$$

IMPROVEMENT OF VOLTA'S BATTERY

It was early suggested that sheets of silver and zinc be soldered together back to back and that a trough be divided into cells by these bimetal sheets being put into grooves cut in the sides and bottom of the trough. This is the reason why one unit of a battery is called a " cell." It was soon found that a more powerful cell could be made if copper, zinc and dilute sulphuric acid were used. The zinc is dissolved by the acid forming zinc sulphate and hydrogen gas, thus:

$$Zn + H_2SO_4 = ZnSO_4 + H_2$$

The hydrogen gas appears as bubbles on the copper and reduces the open circuit voltage (about 0.8 volt per cell) as current is taken from the battery. This is called "polarization." Owing to minute impurities in the zinc, it is attacked by the acid even when no current is taken from the battery, the impurities forming with the zinc a short circuited local cell. This is called " local action," and this difficulty was at first overcome by removing the zinc from the acid when the battery was not in use.

DAVY'S DISCOVERIES

Sir Humphry Davy was a well-known English chemist, and with the aid of powerful batteries constructed for the Royal Institution in London, he made numerous experiments on the chemical effects of electricity. He decomposed a number of substances and discovered the elements boron, potassium and sodium. He heated strips of various metals to incandescence by passing current through them, and showed that platinum would stay incandescent for some time without oxidizing. This was about 1802.

In the early frictional machines, the presence of electricity was shown by the fact that sparks could be obtained. Similarly the breaking of the circuit of a battery would give a spark. Davy, about 1809, demonstrated that this spark could be maintained for a long time with the large battery of 2000 cells he had had constructed. Using two sticks of charcoal connected by wires to the terminals of this very powerful battery, he demonstrated before the Royal Society the light produced by touching the sticks together and then holding them apart horizontally about three inches. The brilliant flame obtained he called an "arc" because of its arch shape, the heated gases, rising, assuming this form. Davy was given the degree of LL. D. for his distinguished research work, and was knighted on the eve of his marriage, April 11, 1812.

RESEARCHES OF OERSTED, AMPÈRE, SCHWEIGGER AND STURGEON

Hans Christian Oersted was a professor of physics at the University of Copenhagen in Denmark. One day in 1819, while addressing his students, he happened to hold a wire, through which current was flowing, over a large compass. To his surprise he saw the compass was deflected from its true position. He promptly made a number of experiments and discovered that by reversing the current the compass was deflected in the opposite direction. Oersted announced his discovery in 1820.

André Marie Ampère was a professor of mathematics in the Ecole Polytechnic in Paris. Hearing of Oersted's discovery, he immediately made some experiments and made the further discovery in 1820 that if the wire is coiled and current passed through it, the coil had all the properties of a magnet.

These two discoveries led to the invention of Schweigger in 1820, of the galvanometer (or "multiplier" as it was then called), a very sensitive instrument for measuring electric currents. It consisted of a delicate compass needle suspended in a coil of many turns of wire. Current in the coil deflected the needle, the direction and amount of deflection indicating the direction and strength of the current. Ampère further made the discovery that currents in opposite directions repel and in the same directions attract each other. He also gave a rule for determining the direction of the current by the deflection of the compass needle. He developed the theory that magnetism is caused by electricity flowing around the circumference of the body magnetised. The AMPERE, the unit of flow of electric current, was named in honor of his discoveries.

In 1825 it was shown by Sturgeon that if a bar of iron were placed in the coil, its magnetic strength would be very greatly increased, which he called an electro-magnet.

OHM'S LAW

Georg Simon Ohm was born in Bavaria, the oldest son of a poor blacksmith. With the aid of friends he went to college and became a teacher. It had been shown that the rate of transfer of heat from one end to the other of a metal bar is proportional to the difference of temperature between the ends. About 1825, Ohm, by analogy and experiment, found that the current in a conductor is proportional to the difference of electric pressure (voltage) between its ends. He further showed that with a given difference of voltage, the current in different conductors is inversely proportional to the resistance of the conductor. Ohm therefore propounded the law that the current flowing in a circuit is equal to the voltage on that circuit divided by the resistance of the circuit. In honor of this discovery, the unit of electrical resistance is called the OHM. This law is usually expressed as:

$$C = \frac{E}{R}$$

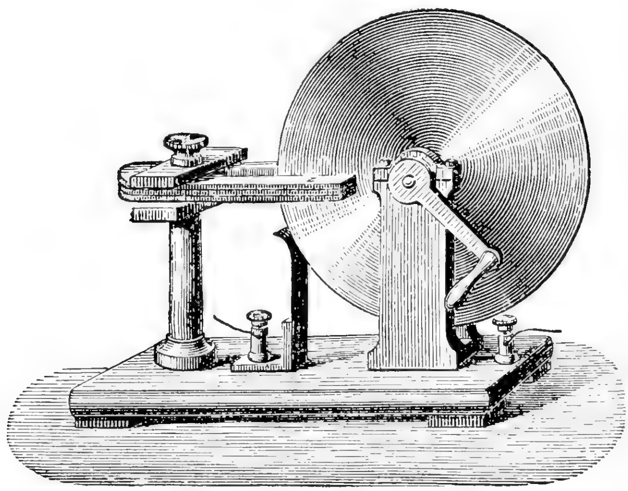
"C" meaning current (in amperes), "E" meaning electromotive force or voltage (in volts) and "R" meaning resistance (in ohms).

This is one of the fundamental laws of electricity and if thoroughly understood, will solve many electrical problems. Thus, if any two of the above units are known, the third can be determined. Examples: An incandescent lamp on a 120-volt circuit consumes 0.4 ampere, hence its resistance under such conditions is 300 ohms. Several trolley cars at the end of a line take 100 amperes to run them and the resistance of the overhead wire from the power house to the trolley cars is half an ohm; the drop in voltage on the line between the power house and trolley cars is therefore 50 volts, so that if the voltage at the power house were 600, it would be 550 volts at the end of the line.

Critics derided Ohm's law so that he was forced out of his position as teacher in the High School in Cologne. Finally after ten years Ohm began to find supporters and in 1841 his law was publicly recognized by the Royal Society of London which presented him with the Copley medal.

INVENTION OF THE DYNAMO

Michael Faraday was an English scientist. Born of parents in poor circumstances, he became a bookbinder and studied books on electricity and chemistry. He finally obtained a position as laboratory assistant to Sir Humphry Davy helping him with his lectures and experiments. He also made a number of experiments himself and succeeded in liquifying chlorine gas for which he was elected to a Fellowship in the Royal Institution in 1824. Following up Oersted's and Ampère's work, he endeavored to find the relation between electricity and magnetism. Finally on Oct. 17, 1831, he made the experiment of moving a permanent bar magnet in and out of a coil of wire connected to a galvanometer. This generated electricity in the coil which deflected the galvanometer needle. A few days after, Oct. 28, 1831, he mounted a copper disk on a shaft so that the disk could be rotated between the poles of a permanent horseshoe magnet.



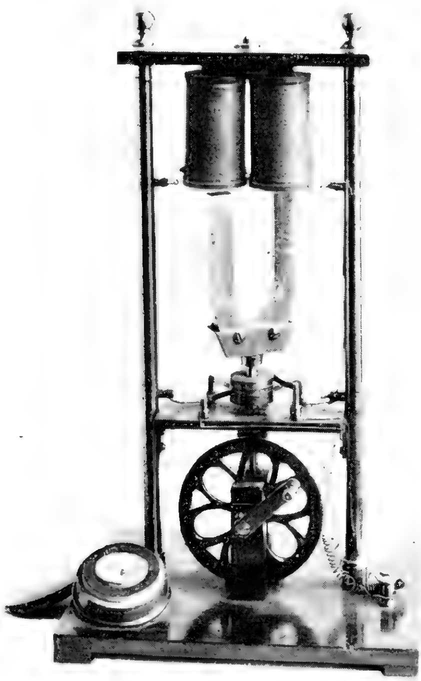
FARADAY'S DYNAMO, 1831.

Faraday discovered that electricity could be generated by means of a permanent magnet. This principle is used in all dynamos.

The shaft and edge of the disk were connected by brushes and wires to a galvanometer, the needle of which was deflected as the disk was rotated. A paper on his invention was read before the Royal Society on November 24, 1831, which appeared in printed form in January, 1832.

Faraday did not develop his invention any further, being satisfied, as in all his work, in pure research. His was a notable invention but it remained for others to make it practicable. Hippolyte Pixii, a Frenchman, made a dynamo in 1832 consisting of a permanent horseshoe magnet which could be rotated between two wire bobbins mounted on a soft iron core. The wires from the bobbins were connected to a pair of brushes touching a commutator mounted on the shaft holding the magnet, and other brushes carried the current from the commutator so that the alternating current generated was rectified into direct current.

E. M. Clarke, an Englishman made, in 1834, another dynamo in which the bobbins rotated alongside of the poles of a permanent



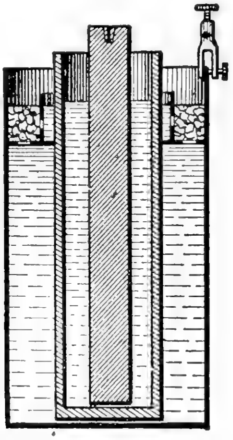
Pixii's Dynamo, 1832.

Pixii made an improvement by rotating a permanent magnet in the neighborhood of coils of wire mounted on a soft iron core. A commutator rectified the alternating current generated into direct current. This dynamo is in the collection of the Smithsonian Institution.

horseshoe magnet. He also made a commutator so that the machine produced direct current. None of these machines gave more than feeble current at low pressure. The large primary batteries that had been made were much more powerful, although expensive to operate. It has been estimated that the cost of current from the 2000-cell battery to operate the demonstration of the arc light by Davy, was six dollars a minute. At present retail rates for electricity sold by lighting companies, six dollars would operate Davy's arc light about 500 hours or 30,000 times as long.

DANIELL'S BATTERY

It was soon discovered that if the zinc electrode were rubbed with mercury (amalgamated), the local action would practically cease, and if the hydrogen bubbles were removed, the operating voltage of the cell would be increased. John Frederic Daniell, an English chemist, invented a cell in 1836 to overcome these difficulties. His



DANIELL'S CELL, 1836.

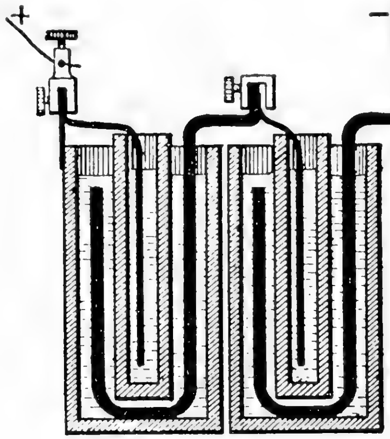
Daniell invented a battery consisting of zinc, copper and copper sulphate. Later the porous cup was dispensed with, which was used to keep the sulphuric acid formed separate from the solution of copper sulphate, the two liquids then being kept apart by their difference in specific gravity. It was then called the Gravity Battery and for years was used in telegraphy.

cell consisted of a glass jar containing a saturated solution of copper sulphate ($CuSO_4$). A copper cylinder, open at both ends and perforated with holes, was put into this solution. On the outside of the copper cylinder there was a copper ring, located below the surface of the solution, acting as a shelf to support crystals of copper sulphate. Inside the cylinder there was a porous earthenware jar containing dilute sulphuric acid and an amalgamated zinc rod. The two liquids were therefore kept apart but in contact with each other through the pores of the jar. The hydrogen gas given off by the action of the sulphuric acid on the zinc, combined with the dissolved copper sulphate, formed sulphuric acid and metallic copper. The latter was deposited on the copper cylinder which acted as the other electrode. Thus the copper sulphate acted as a depolarizer.

The chemical reactions in this cell are,

In inner porous jar: $Zn + H_2SO_4 = ZnSO_4 + H_2$
In outer glass jar: $H_2 + CuSO_4 = H_2SO_4 + Cu$

This cell had an open circuit voltage of a little over one volt. Later the porous cup was dispensed with, the two liquids being kept apart



GROVE'S CELL, 1838.

This consisted of zinc, sulphuric acid, nitric acid and platinum. It made a very powerful battery. The nitric acid is called the depolarizer as it absorbs the hydrogen gas formed, thus improving the operating voltage.

by the difference of their specific gravities. This was known as the Gravity cell, and for years was used in telegraphy.

GROVE'S BATTERY

Sir William Robert Grove, an English Judge and scientist, invented a cell in 1838 consisting of a platinum electrode in strong nitric acid in a porous earthenware jar. This jar was put in dilute sulphuric acid in a glass jar in which there was an amalgated zinc plate for the other electrode. This had an open circuit voltage of about 1.9 volts. The porous jar was used to prevent the nitric acid from attacking the zinc. The nitric acid was used for the purpose of combining with the hydrogen gas set free by the action of the sulphuric acid on the zinc, and hence was the depolarizing agent. Hydrogen combining with nitric acid forms nitrous peroxide and water. Part of the nitrous peroxide is dissolved in the water, and the rest escapes as fumes which, however, are very suffocating.

The chemical equations of this cell are as follows:

In outer glass jar: $Zn+H_2SO_4=ZnSO_4+H_2$
In inner porous jar: $H_2+2HNO_3=N_2O_4+2H_2O$

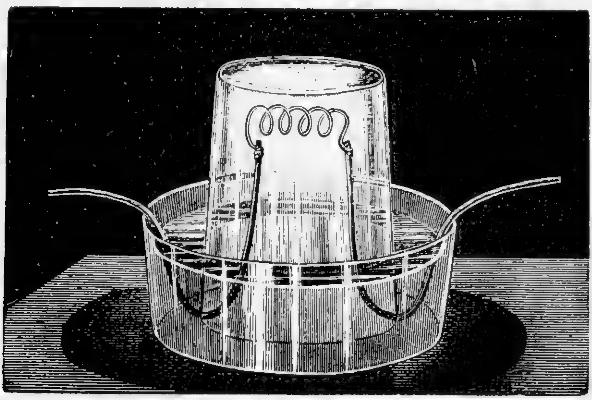
An interesting thing about Grove's cell is that it was planned in accordance with a theory. Grove knew that the electrical energy of the zinc-sulphuric acid cell came from the chemical affinity of the two reagents, and if the hydrogen gas set free could be combined with oxygen (to form water—H_2O), such chemical affinity should increase the strength of the cell. As the hydrogen gas appears at the other electrode, the oxidizing agent should surround that electrode. Nitric acid was known at that time as one of the most powerful oxidizing liquids, but as it attacks copper, he used platinum for the other electrode. Thus he not only overcame the difficulty of polarization by the hydrogen gas, but also increased the voltage of the cell by the added chemical action of the combination of hydrogen and oxygen.

GROVE'S DEMONSTRATION OF INCANDESCENT LIGHTING

In 1840 Grove made an experimental lamp by attaching the ends of a coil of platinum wire to copper wires, the lower parts of which were well varnished for insulation. The platinum wire was covered by a glass tumbler, the open end set in a glass dish partly filled with water. This prevented draughts of air from cooling the incandescent platinum, and the small amount of oxygen of the air in the tumbler reduced the amount of oxidization of the platinum that would otherwise occur. With current supplied by a large number of cells of his battery, he lighted the auditorium of the Royal Institution with these lamps during one of the lectures he gave. This lamp gave only a feeble light as there was danger of melting the platinum and platinum gives but little light unless operated close to its melting temperature. It also required a lot of current to operate it as the air tended to cool the incandescent platinum. The demonstration was only of scientific interest, the cost of current being much too great (estimated at several hundred dollars a kilowatt hour) to make it commercial.

GRENET BATTERY

It was discovered that chromic anhydride gives up oxygen easier than nitric acid and consequently if used would give a higher voltage than Grove's nitric acid battery. It also has the advantage of a lesser tendency to attack zinc directly if it happens to come in contact with it. Grenet developed a cell having a liquid consisting of a mixture of potassium bichromate ($K_2Cr_2O_7$) and sulphuric acid. A porous cell was therefore not used to keep the two liquids apart. This had the



Grove's Incandescent Lamp, 1840.

Grove made an experimental lamp, using platinum for the burner which was protected from draughts of air by a glass tumbler.

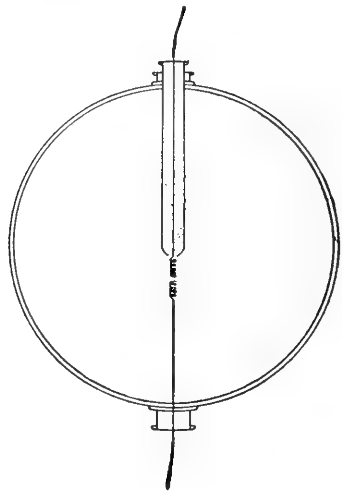
advantage of reducing the internal resistance. The chemical reaction was:

$K_2Cr_2O_7$ (potassium bichromate) $+ 7H_2SO_4$ (sulphuric acid) $+ 3Zn$ (zinc) $= 3ZnSO_4$ (zinc sulphate) $+ K_2SO_4$ (potassium sulphate) $+ Cr_2(SO_4)_3$ (chromium sulphate) $+ 7H_2O$ (water).

In order to prevent the useless consumption of zinc on open circuit, the zinc was attached to a sliding rod and could be drawn up into the neck of the bottle-shaped jar containing the liquid.

DE MOLEYNS' INCANDESCENT LAMP

Frederick De Moleyns, an Englishman, has the honor of having obtained the first patent on an incandescent lamp. This was in 1841 and his lamp was quite novel. It consisted of a spherical glass globe, in the upper part of which was a tube containing powdered charcoal. This tube was open at the bottom inside the globe and through it ran a platinum wire, the end below the tube being coiled. Another platinum wire coiled at its upper end came up through the lower part of the globe but did not quite touch the other platinum coil. The powdered charcoal filled the two coils of platinum wire and bridged the gap between. Current passing through this charcoal bridge heated it to incandescence. The air in the globe having been removed as far as was possible with the hand air pumps then available, the charcoal did not immediately burn up, the small amount consumed being replaced by the supply in the tube. The idea was ingenious but the



De Moleyns' Incandescent Lamp, 1841.

This consisted of two coils of platinum wire containing powdered charcoal operating in a vacuum. It is only of interest as the first incandescent lamp on which a patent (British) was granted.

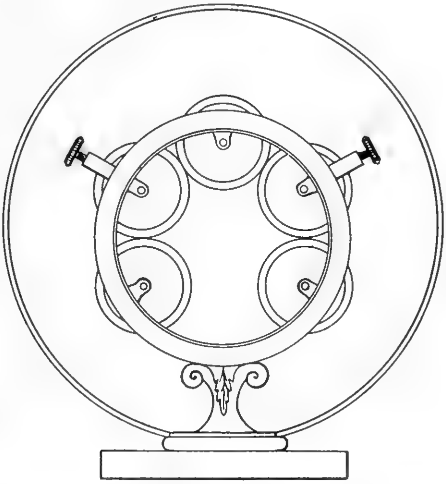
lamp was impractical as the globe rapidly blackened from the evaporation of the incandescent charcoal.

EARLY DEVELOPMENTS OF THE ARC LAMP

It had been found that most of the light of the arc came from the tip of the positive electrode, and that the charcoal electrodes were rapidly consumed, the positive electrode about twice as fast as the negative. Mechanisms were designed to take care of this, together with devices to start the arc by allowing the electrodes to touch each other and then pulling them apart the proper distance. This distance varied from one-eighth to three-quarters of an inch.

In 1840 Bunsen, the German chemist who invented the bunsen burner, devised a process for making hard dense carbon pencils which lasted much longer than the charcoal previously used. The dense carbon from the inside of the retorts of gas making plants was ground up and mixed with molasses, moulded into shape and baked at a high temperature. Bunsen also, in 1843, cheapened Grove's battery by substituting a hard carbon plate in place of the platinum electrode.

Thomas Wright, an Englishman, was the first to patent an arc lamp. This was in 1845, and the lamp was a hand regulated device consisting

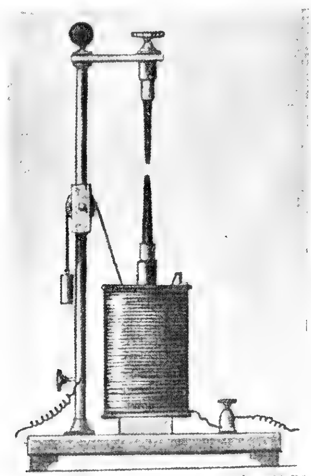


Wright's Arc Lamp, 1845.

This lamp is also only of interest as the first arc lamp on which a patent (British) was granted. Four arcs played between the five carbon discs.

of five carbon disks normally touching each other and rotated by clockwork. Two of the disks could be drawn outward by thumb screws, which was to be done after the current was turned on thus establishing four arcs, one between each pair of disks. The next year, 1846, W. E. Staite, another Englishman, made an arc lamp having two vertical carbon pencils. The upper was stationary. The lower was movable and actuated by clockwork directed by ratchets which in turn were regulated by an electro-magnet controlled by the current flowing through the arc. Thus the lower carbon would be moved up or down as required.

Archereau, a Frenchman, made a very simple arc lamp in 1848. The upper carbon was fixed and the lower one was mounted on a piece of iron which could be drawn down into a coil of wire. The weight of the lower electrode was overbalanced by a counterweight, so that when no current was flowing the two carbons would touch. When current was turned on, it flowed through the two carbons and through the coil of wire (solenoid) which then became energized and pulled the lower carbon down, thus striking the arc. Two of these arc lamps were installed in Paris and caused considerable excitement. After a few weeks of unreliable operation, it was found that the cost of current from the batteries was much too great to continue their



ARCHEREAU'S ARC LAMP, 1848.

This simple arc was controlled by an electro-magnet, and two lamps were installed for street lighting in Paris, current being obtained from batteries.

use commercially. The dynamo had not progressed far enough to permit its use.

JOULE'S LAW

Joule was an Englishman, and in 1842 began investigating the relation between mechanical energy and heat. He first showed that, by allowing a weight to drop from a considerable height and turn a paddle wheel in water, the temperature of the water would increase in relation to the work done in turning the wheel. It is now known that 778 foot-pounds (1 lb. falling 778 feet, 10 lbs. falling 77.8 feet or 778 lbs. falling one foot, etc.) is the mechanical equivalent of energy equal to raising one pound of water one degree Fahrenheit.

The rate of energy (power) is the energy divided by a unit of time; thus one horsepower is 33,000 foot-pounds per minute. Joule next investigated the relation between heat and electric current. He made a device consisting of a vessel of water in which there were a thermometer and an insulated coil of wire having a considerable resistance. He found that an electric current heated the water, and making many combinations of the amount and length of time of current flowing and of the resistance of the wire, he deduced the law that the energy in an electric circuit is proportional to the square of the amount of current flowing multiplied by the length of time and multiplied by the resistance of the wire.

The rate of electrical energy (electric power) is therefore proportional to the square of current multiplied by the resistance. The electrical unit of power is now called the WATT, named in honor of James Watt, the Englishman, who made great improvements to the steam engine about a century ago. Thus, watts $= C^2R$ and substituting the value of R from Ohm's law, $C = \frac{E}{R}$, we get

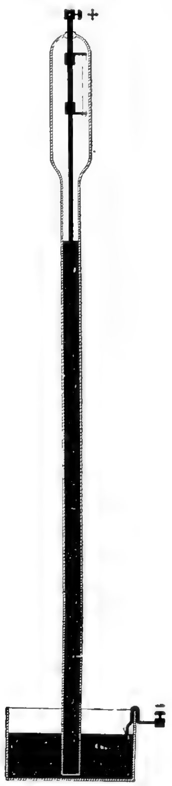
$$\text{Watts} = \text{Volts} \times \text{Amperes}$$

The watt is a small unit of electric power, as can be seen from the fact that 746 watts are equal to one horsepower. The kilowatt, kilo being the Greek word for thousand, is 1000 watts.

This term is an important one in the electrical industry. For example, dynamos are rated in kilowatts, expressed as KW; the largest one made so far is 50,000 KW which is 66,666 horsepower. Edison's first commercial dynamo had a capacity of 6 KW although the terms watts and kilowatts were not in use at that time. The ordinary sizes of incandescent lamps now used in the home are 25, 40 and 50 watts.

STARR'S INCANDESCENT LAMP

J. W. Starr, an American, of Cincinnati, Ohio, assisted financially by Peabody, the philanthropist, went to England where he obtained a patent in 1845 on the lamps he had invented, although the patent was taken out under the name of King, his attorney. One is of passing interest only. It consisted of a strip of platinum, the active length of which could be adjusted to fit the battery strength used, and was covered by a glass globe to protect it from draughts of air. The other, a carbon lamp, was the first real contribution to the art. It consisted of a rod of carbon operating in the vacuum above a column of mercury (Torrecellium vacuum) as in a barometer. A heavy platinum wire was sealed in the upper closed end of a large glass tube, and connected to the carbon rod by an iron clamp. The lower end of the carbon rod was fastened to another iron clamp, the two clamps being held in place and insulated from each other by a porcelain rod. Attached to the lower clamp was a long copper wire. Just below the lower clamp,



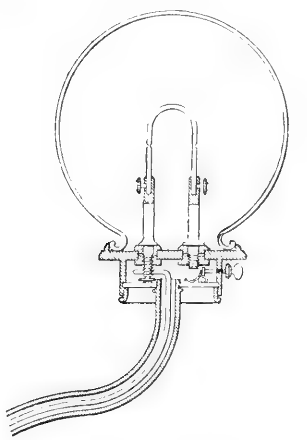
STARR'S INCANDESCENT LAMP, 1845.

This consisted of a short carbon pencil operating in the vacuum above a column of mercury.

the glass tube was narrowed down and had a length of more than 30 inches. The tube was then filled with mercury, the bottom of the tube being put into a vessel partly full of mercury. The mercury ran out of the enlarged upper part of the tube, coming to rest in the narrow part of the tube as in a barometer, so that the carbon rod was then in a vacuum. One lamp terminal was the platinum wire extending through the top of the tube, and the other was the mercury. Several of these lamps were put on exhibition in London, but were not a commercial success as they blackened very rapidly. Starr started his return trip to the United States the next year, but died on board the ship when he was but 25 years old.

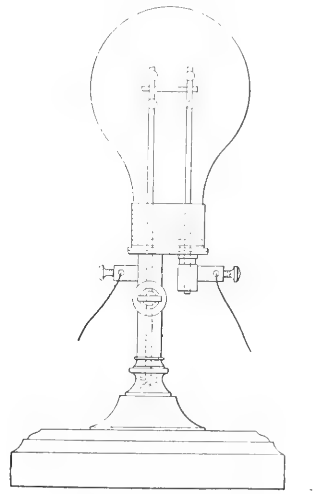
OTHER EARLY INCANDESCENT LAMPS

In 1848 W. E. Staite, who two years previously had made an arc lamp, invented an incandescent lamp. This consisted of a platinum-iridium burner in the shape of an inverted U, covered by a glass globe.



Staite's Incandescent Lamp, 1848.

The burner was of platinum and iridium.

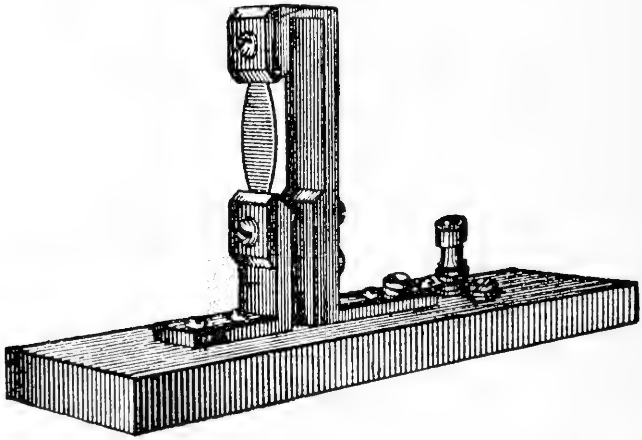


Roberts' Incandescent Lamp, 1852.

It had a graphite burner operating in vacuum.

It had a thumb screw for a switch, the whole device being mounted on a bracket which was used for the return wire. E. C. Shepard, another Englishman, obtained a patent two years later on an incandescent lamp consisting of a weighted hollow charcoal cylinder the end of which pressed against a charcoal cone. Current passing through this high resistance contact, heated the charcoal to incandescence. It operated in a glass globe from which the air could be exhausted. M. J. Roberts obtained an English patent in 1852 on an incandescent lamp. This had a graphite rod for a burner, which could be renewed, mounted in a glass globe. The globe was cemented to a metallic cap fastened to a piece of pipe through which the air could be exhausted. After being exhausted, the pipe, having a stop cock, could be screwed on a stand to support the lamp.

Moses G. Farmer, a professor at the Naval Training Station at Newport, Rhode Island, lighted the parlor of his home at 11 Pearl Street, Salem, Mass., during July, 1859, with several incandescent lamps having a strip of platinum for the burner. The novel feature of this lamp was that the platinum strip was narrower at the terminals than in the center. Heat is conducted away from the terminals and by making the burner thin at these points, the greater resistance



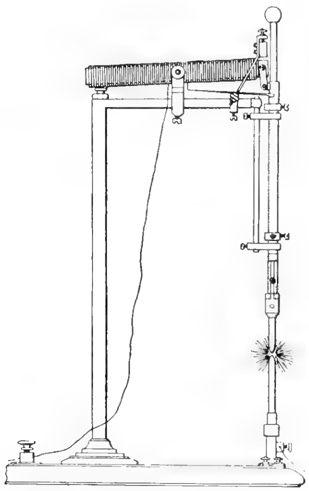
FARMER'S INCANDESCENT LAMP, 1859.

This experimental platinum lamp was made by Professor Farmer and several of them lighted the parlor of his home in Salem, Mass.

of the ends of the burner absorbed more electrical energy thus offsetting the heat being conducted away. This made a more uniform degree of incandescence throughout the length of the burner, and Prof. Farmer obtained a patent on this principle many years later (1882).

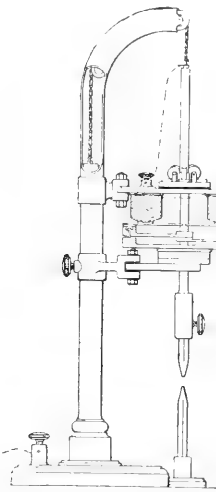
FURTHER ARC LAMP DEVELOPMENTS

During the ten years, 1850 to 1860, several inventors developed arc lamp mechanisms. Among them was M. J. Roberts, who had invented the graphite incandescent lamp. In Roberts' arc lamp, which he patented in 1852, the lower carbon was stationary. The upper carbon fitted snugly into an iron tube. In the tube was a brass covered iron rod, which by its weight could push the upper carbon down the tube so the two carbons normally were in contact. An electro-magnet in series with the arc was so located that, when energized, it pulled up the iron tube. This magnet also held the brass covered iron rod from pushing the upper carbon down the tube so that the two carbons were pulled apart, striking the arc. When the arc went out, the iron tube dropped back into its original position, the brass covered iron rod was released, pushing the upper carbon down the tube until the two carbons again touched. This closed the circuit again, striking the arc as before.



ROBERTS' ARC LAMP, 1852.

The arc was controlled by an electro-magnet which held an iron tube to which the upper carbon was fastened.



SLATER AND WATSON'S ARC LAMP, 1852.

Clutches were used for the first time in this arc lamp to feed the carbons.

In the same year (1852) Slater and Watson obtained an English patent on an arc lamp in which the upper carbon was movable and held in place by two clutches actuated by electro-magnets. The lower carbon was fixed, and normally the two carbons touched each other. When current was turned on, the electro-magnet lifted the clutches which gripped the upper carbon, pulling it up and striking the arc. This was the first time that a clutch was used to allow the carbon to feed as it became consumed.

Henry Chapman, in 1855, made an arc in which the upper carbon was allowed to feed by gravity, but held in place by a chain wound around a wheel. On this wheel was a brake actuated by an electro-magnet. The lower carbon was pulled down by an electro-magnet working against a spring. When no current was flowing or when the arc went out, the two carbons touched. With current on, one electro-magnet set the brake and held the upper carbon stationary. The other electro-magnet pulled the lower carbon down, thus striking the arc.

None of these mechanisms regulated the length of the arc. It was not until 1856 that Joseph Lacassagne and Henry Thiers, Frenchmen, invented the so-called "differential" method of control, which made the carbons feed when the arc voltage, and hence length, became too great. This principle was used in commercial arc lamps several years afterward when they were operated on series circuits, as it had the added advantage of preventing the feeding of one arc lamp affect-

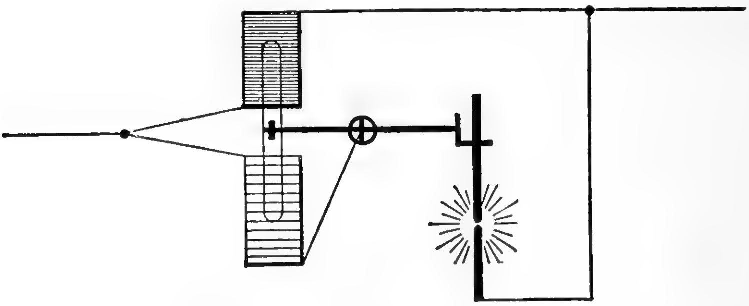
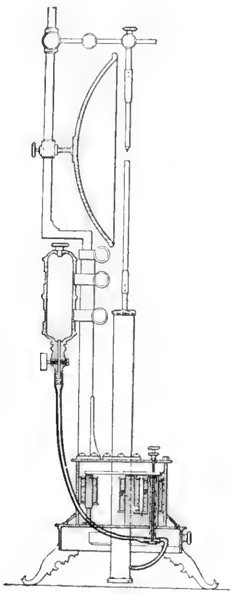


Diagram of "Differential" Method of Control of an Arc Lamp.

This principle, invented by Lacassagne and Thiers, was used in all arc lamps when they were commercially introduced on a large scale more than twenty years later.

ing another on the same circuit. This differential control consists in principle of two electro-magnets, one in series with, and opposing the pull of the other which is in shunt with the arc. The series magnet pulls the carbons apart and strikes the arc. As the arc increases in length, its voltage rises, thereby increasing the current flowing through the shunt magnet. This increases the strength of the shunt magnet and, when the arc becomes too long, the strength of the shunt becomes greater than that of the series magnet, thus making the carbons feed.

The actual method adopted by Lacassagne and Thiers was different from this, but it had this principle. They used a column of mercury on which the lower carbon floated. The upper carbon was stationary. The height of the mercury column was regulated by a valve connected with a reservoir of mercury. The pull of the series magnet closed the valve fixing the height of the column. The pull of the shunt magnet tended to open the valve, and when it overcame the pull of the series magnet it allowed mercury to flow from the reservoir, raising the height of the column bringing the carbons nearer together. This reduced the arc voltage and shunt magnet strength until the valve closed again. Thus the carbons were always kept the proper distance apart. In first starting the arc, or if the arc should

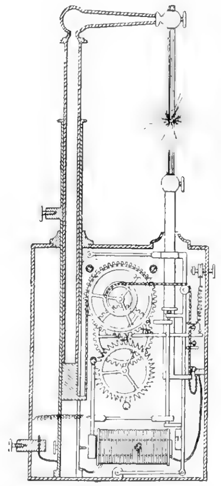


Lacassagne and Thiers' Differentially Controlled Arc Lamp, 1856.

The lower carbon floated on a column of mercury whose height was "differentially" controlled by series and shunt magnets.

go out, current would only flow through the shunt magnet, bringing the two carbons together until they touched. Current would then flow through the contact of the two carbons and through the series magnet, shutting the valve. There were no means of pulling the carbons apart to strike the arc. Current flowing through the high resistance of the poor contact of the two carbons, heated their tips to incandescence. The incandescent tips would begin to burn away, thus after a time starting an arc. The arc, however, once started was maintained the proper length.

In 1857, Serrin took out his first patent on an arc lamp, the general principles of which were the same as in others he made. The mechanism consisted of two drums, one double the diameter of the other. Both carbons were movable, the upper one feeding down, and the lower one feeding up, being connected with chains wound around the drums. The difference in consumption of the two carbons was therefore compensated for by the difference in size of the drums, thus maintaining the location of the arc in a fixed position. A train



SERRIN'S ARC LAMP, 1857.

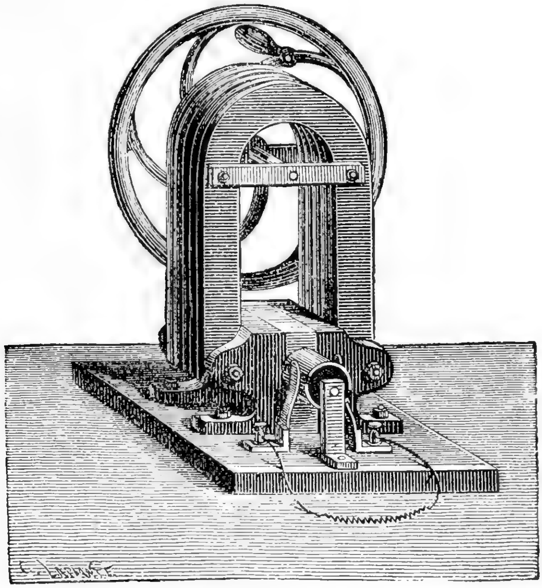
This type of arc was not differentially controlled but was the first commercial lamp later used. Both carbons were movable, held by chains wound around drums which were controlled by ratchets actuated by an electro-magnet.

of wheels controlled by a pawl and regulated by an electro-magnet, controlled the movement of the carbons. The weight of the upper carbon and its holder actuates the train of wheels.

DEVELOPMENT OF THE DYNAMO, 1840-1860

During the first few years after 1840 the dynamo was only a laboratory experiment. Woolrich devised a machine which had several pairs of magnets and double the number of coils in order to make the current obtained less pulsating. Wheatstone in 1845 patented the use of electro-magnets in place of permanent magnets. Brett in 1848 suggested that the current, generated in the coils, be allowed to flow through a coil surrounding each permanent magnet to further strengthen the magnets. Pulvermacher in 1849 proposed the use of thin plates of iron for the bobbins, to reduce the eddy currents generated in the iron. Sinsteden in 1851 suggested that the current from a permanent magnet machine be used to excite the field coils of an electro-magnet machine.

In 1855 Soren Hjorth, of Copenhagen, Denmark, patented a dynamo having both permanent and electro-magnets, the latter being



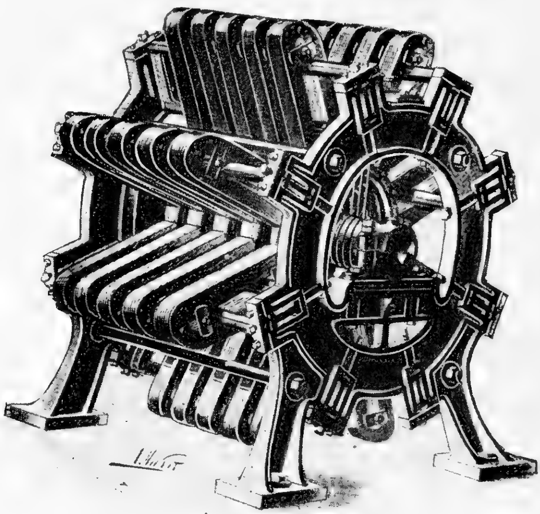
SIEMENS' DYNAMO, 1856.

This dynamo was an improvement over others on account of the construction of its "shuttle" armature.

excited by currents first induced in the bobbins by the permanent magnets. In 1856 Dr. Werner Siemens invented the shuttle wound armature. This consisted of a single coil of wire wound lengthwise and counter sunk in a long cylindrical piece of iron. This revolved between the magnet poles which were shaped to fit the cylindrical armature.

THE FIRST COMMERCIAL INSTALLATION OF AN ELECTRIC LIGHT

In 1862 a Serrin type of arc lamp was installed in the Dungeness lighthouse in England. Current was supplied by a dynamo made by the Alliance Company, which had been originally designed in 1850 by Nollet, a professor of Physics in the Military School in Brussels. Nollet's original design was of a dynamo having several rows of permanent magnets mounted radially on a stationary frame, with an equal number of bobbins mounted on a shaft which rotated and had a commutator so direct current could be obtained. A company was formed to sell hydrogen gas for illuminating purposes, the gas to be made by the decomposition of water with current from this machine.



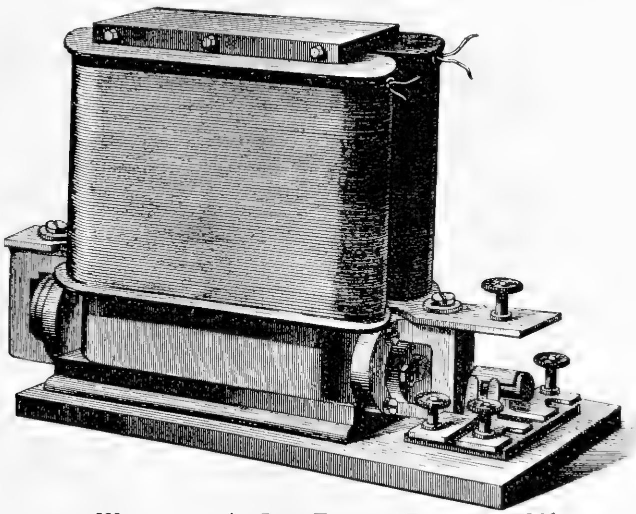
ALLIANCE DYNAMO, 1862.
This was the dynamo used in the first commercial installation of an arc light in the Dungeness Lighthouse, England, 1862.

Nollet died and the company failed, but it was reorganized as the Alliance Company a few years later to exploit the arc lamp.

About the only change made in the dynamo was to substitute collector rings for the commutator to overcome the difficulties of commutation. Alternating current was therefore generated in this first commercial machine. It had a capacity for but one arc light, which probably consumed less than ten amperes at about 45 volts, hence delivered in the present terminology not over 450 watts or about two-thirds of a horsepower. As the bobbins of the armature undoubtedly had a considerable resistance, the machine had an efficiency of not over 50 per cent and therefore required at least one and a quarter horsepower to drive it.

FURTHER DYNAMO DEVELOPMENTS

In the summer of 1886 Sir Charles Wheatstone constructed a self-excited machine on the principle of using the residual magnetism in the field poles to set up a feeble current in the armature which, passing through the field coils, gradually strengthened the fields until they built up to normal strength. It was later found that this idea had been thought of by an unknown man, being disclosed by a clause in a provisional 1858 English patent taken out by his agent. Wheatstone's machine was shown to the Royal Society in London and a

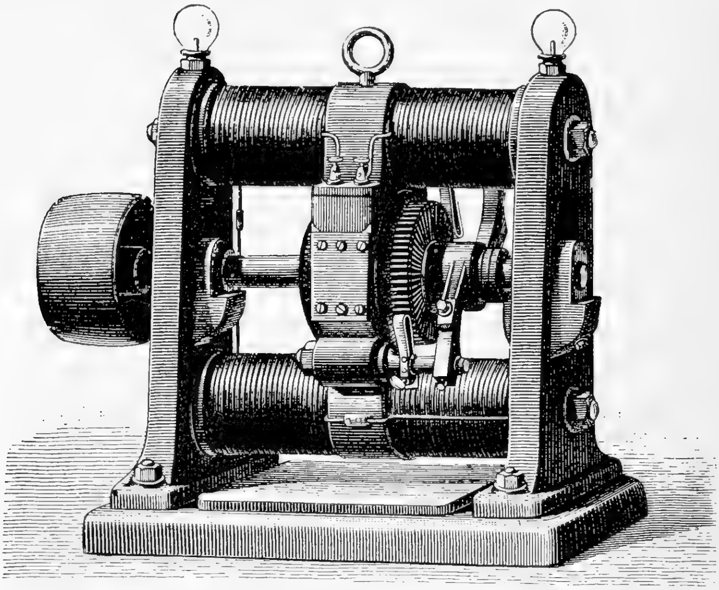


WHEATSTONE'S SELF-EXCITED DYNAMO, 1866.
This machine was the first self-excited dynamo by use of the residual magnetism in the field poles.

paper on it read before the Society on February 14, 1867. The field coils were shunt wound.

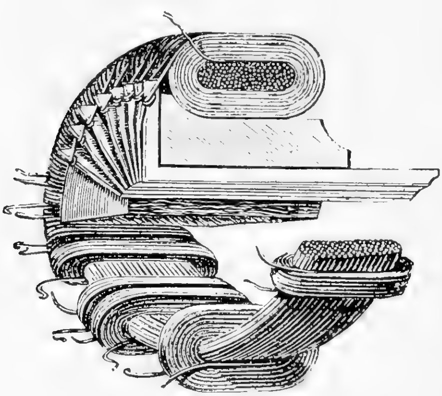
Dr. Werner Siemens also made a self-excited machine, having series fields, a paper on which was read before the Academy of Sciences in Berlin on January 17, 1867. This paper was forwarded to the Royal Society in London and presented at the same meeting at which Wheatstone's dynamo was described. Wheatstone probably preceded Siemens in this re-discovery of the principle of self-excitation, but both are given the merit of it. However, S. A. Varley on December 24, 1866, obtained a provisional English patent on this, which was not published until July, 1867.

In 1870 Gramme, a Frenchman, patented his well-known ring armature. The idea had been previously thought of by Elias, a



GRAMME'S DYNAMO, 1871.

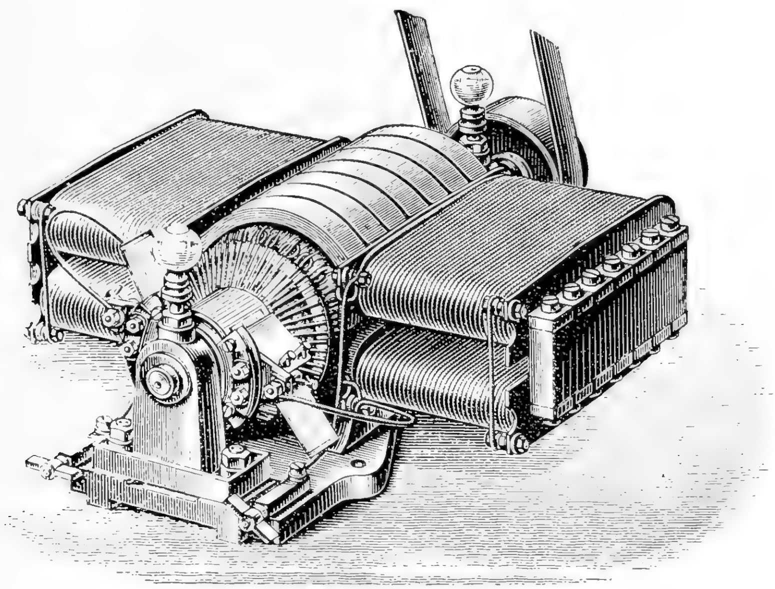
These were commercially used, their main feature being the "ring" wound armature.



GRAMME'S "RING" ARMATURE.

Wire coils, surrounding an iron wire core, were all connected together in an endless ring, each coil being tapped with a wire connected to a commutator bar.

Hollander, in 1842, and by Pacinnotti, an Italian, as shown by the crude motors (not dynamos) they had made. Gramme's armature consisted of an iron wire core coated with a bituminous compound in order to reduce the eddy currents. This core was wound with insulated wire coils, all connected together in series as one single endless coil. Each coil was tapped with a wire connected to a commutator bar. His first machine, having permanent magnets for fields, was submitted to the French Academy of Sciences in 1871. Later



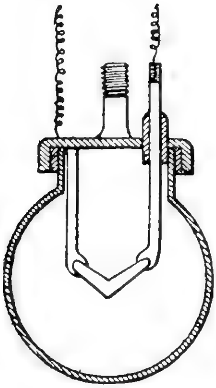
ALTENECK'S DYNAMO WITH "DRUM" WOUND ARMATURE, 1872.
The armature winding was entirely on the surface of the armature core, a principle now used in all dynamos.

machines were made with self-excited field coils, which were used in commercial service. They had, however a high resistance armature, so that their efficiency did not exceed 50 per cent.

Von Hefner Alteneck, an engineer with Siemens, invented the drum wound armature in 1872. The wires of the armature were all on the surface of the armature core, the wires being tapped at frequent points for connection with the commutator bars. Thus in the early seventies, commercial dynamos were available for use in arc lighting, and a few installations were made in Europe.

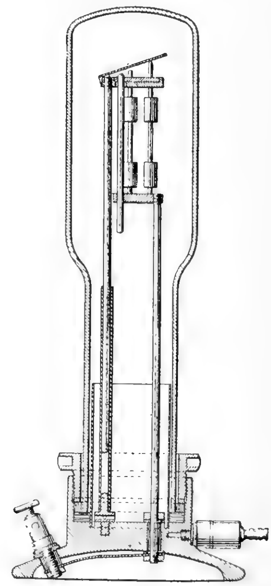
RUSSIAN INCANDESCENT LAMP INVENTORS

In 1872 Lodyguine, a Russian scientist, made an incandescent lamp consisting of a " V " shaped piece of graphite for a burner, which operated in nitrogen gas. He lighted the Admiralty Dockyard at St. Petersburg with about two hundred of these lamps. In 1872 the Russian Academy of Sciences awarded him a prize of 50,000 rubles (a lot of real money at that time) for his invention. A company with a capital of 200,000 rubles (then equal to about $100,000)



LODYGUINE'S INCANDESCENT LAMP, 1872.

The burner was made of graphite and operated in nitrogen gas.

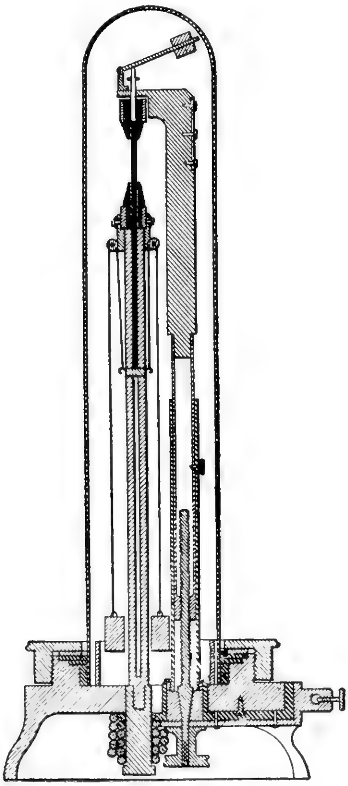


KONN'S INCANDESCENT LAMP, 1875.

In this lamp the graphite rods operated in a vacuum.

was formed but as the lamp was so expensive to operate and had such a short life, about twelve hours, the project failed.

Kosloff, another Russian, in 1875 patented a graphite in nitrogen incandescent lamp, which had several graphite rods for burners, so arranged that when one failed another was automatically connected. Konn, also a Russian, made a lamp similar to Kosloff's except that the graphite rods operated in a vacuum. Bouliguine, another Russian, in 1876 made an incandescent lamp having a long graphite rod, only the upper part of which was in circuit. As this part burned out, the rod was automatically pushed up so that a fresh portion then was in circuit. It operated in a vacuum. None of these lamps was commercial as they blackened rapidly and were too expensive to maintain.

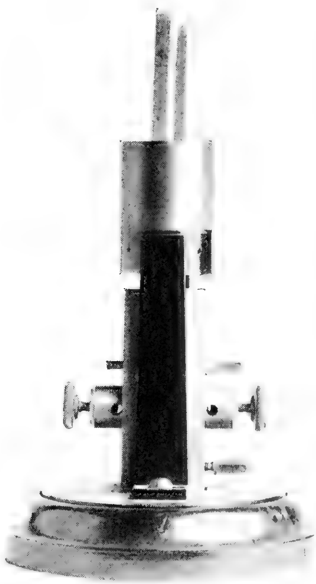


BOULIGUINE'S INCANDESCENT LAMP, 1876.

A long graphite rod, the upper part of which only was in circuit, operated in vacuum. As this part burned out, the rod was automatically shoved up, a fresh portion then being in the circuit.

THE JABLOCHKOFF "CANDLE"

Paul Jablochkoff was a Russian army officer and an engineer. In the early seventies he came to Paris and developed a novel arc light. This consisted of a pair of carbons held together side by side and insulated from each other by a mineral known as kaolin which vaporized as the carbons were consumed. There was no mechanism, the arc being started by a thin piece of carbon across the tips of the carbons. Current burned this bridge, starting the arc. The early carbons were about five inches long, and the positive carbon was twice as thick as the negative to compensate for the unequal consumption on direct current. This, however, did not work satisfactorily. Later the length of the carbons was increased, the carbon made of equal

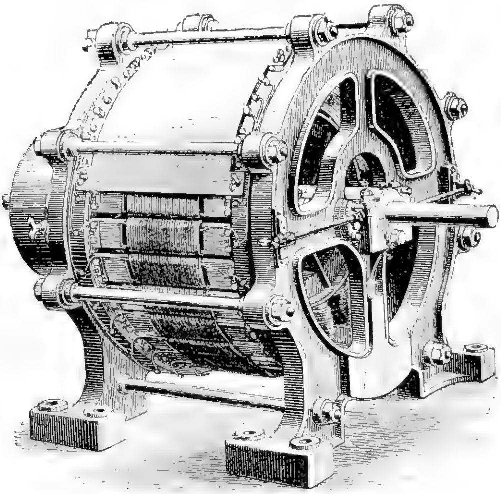


JABLOCHKOFF "CANDLE," 1876.

This simple arc consisted of a pair of carbons held together side by side and insulated from each other by kaolin. Several boulevards in Paris were lighted with these arc lights. This arc lamp is in the collection of the Smithsonian Institution.

thickness and burned on alternating current of about eight or nine amperes at about 45 volts. He made an alternating current generator which had a stationary exterior armature with interior revolving field poles. Several "candles," as they were called, were put in one fixture to permit all night service and an automatic device was developed, located in each fixture, so that should one "candle" go out for any reason, another was switched into service.

In 1876 many of these "candles" were installed and later several of the boulevards in Paris were lighted with them. This was the first large installation of the arc light, and was the beginning of its commercial introduction. Henry Wilde made some improvements in the candle by eliminating the kaolin between the carbons which gave Jablochkoff's arc its peculiar color. Wilde's arc was started by allowing the ends of the carbons to touch each other, a magnet swinging them apart thus striking the arc.



JABLOCHKOFF'S ALTERNATING CURRENT DYNAMO, 1876.

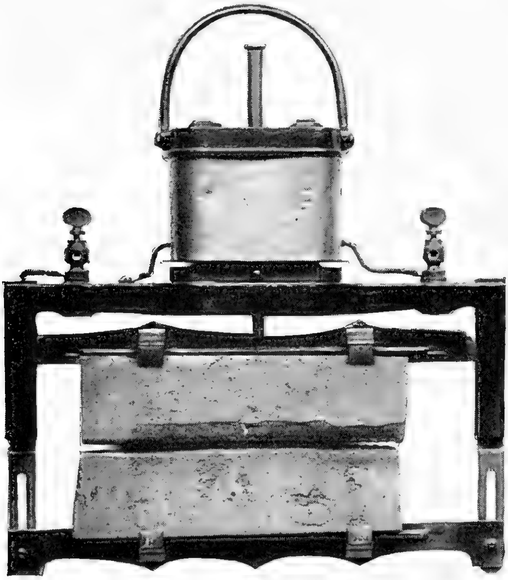
This dynamo had a stationary exterior armature and internal revolving field poles. Alternating current was used for the Jablochkoff "candle" to overcome the difficulties of unequal consumption of the carbons on direct current.

COMMERCIAL INTRODUCTION OF THE DIFFERENTIALLY CONTROLLED ARC LAMP

About the same time Lontin, a Frenchman, improved Serrin's arc lamp mechanism by the application of series and shunt magnets. This is the differential principle which was invented by Lacassagne and Thiers in 1855 but which apparently had been forgotten. Several of these lamps were commercially installed in France beginning with 1876.

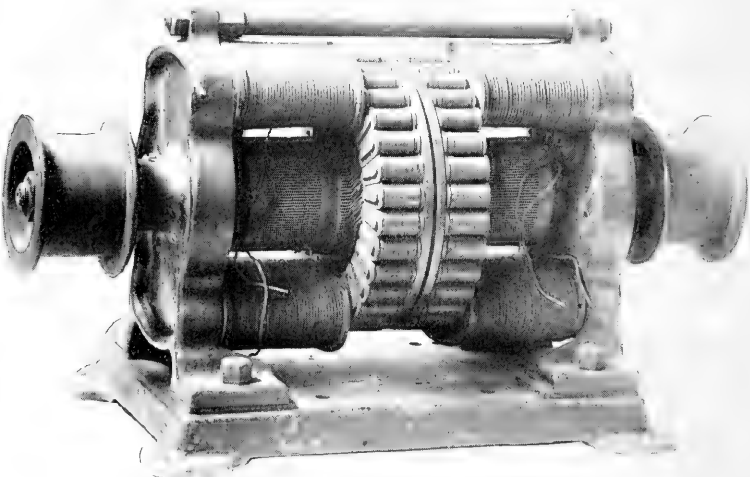
ARC LIGHTING IN THE UNITED STATES

About 1875 William Wallace of Ansonia, Connecticut, made an arc light consisting of two rectangular carbon plates mounted on a wooden frame. The arc played between the two edges of the plates,



Wallace-Farmer Arc Lamp, 1875.

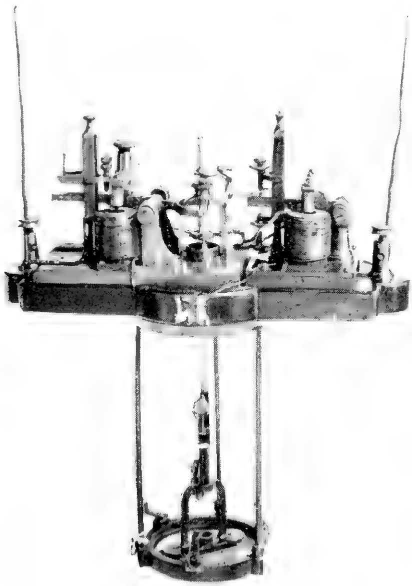
This "differentially controlled" arc lamp consisted of two slabs of carbon between which the arc played. In the original lamp the carbon slabs were mounted on pieces of wood held in place by bolts, adjustment being made by hitting the upper carbon slab with a hammer. This lamp is in the collection of the Smithsonian Institution.



Wallace-Farmer Dynamo, 1875.

This was the first commercial dynamo used in the United States for arc lighting. This dynamo is in the collection of the Smithsonian Institution.

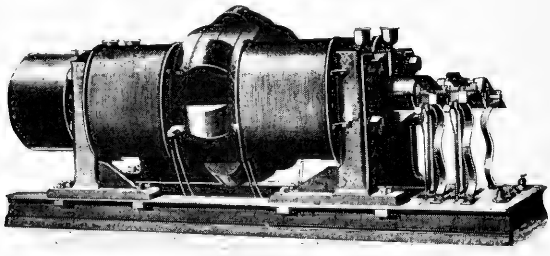
which lasted much longer than rods. When the edges had burned away so that the arc then became unduly long, the carbon plates were brought closer together by hitting them with a hammer. Wallace became associated with Moses G. Farmer, and they improved this crude arc by fastening the upper carbon plate to a rod which was held by a clutch controlled by a magnet. This magnet had two coils in one, the inner winding in series with the arc, and outer one in shunt and opposing the series winding. The arc was therefore differentially controlled.



Weston's Arc Lamp, 1876.
This lamp is in the collection of the Smithsonian Institution.

They also developed a series wound direct current dynamo. The armature consisted of a number of bobbins, all connected together in an endless ring. Each bobbin was also connected to a commutator bar. There were two sets of bobbins, commutators and field poles, the equivalent of two machines in one, which could be connected either to separate circuits, or together in series on one circuit. The Wallace-Farmer system was commercially used. The arc consumed about 20 amperes at about 35 volts, but as the carbon plates cooled the arc, the efficiency was poor. The arc flickered back and forth on the edges of the carbons casting dancing shadows. The carbons, while lasting about 50 hours, were not uniform in density, so the arc would flare up and cast off soot and sparks.

Edward Weston of Newark, New Jersey, also developed an arc lighting system. His commercial lamp had carbon rods, one above the other, and the arc was also differentially controlled. An oil dash pot



Brush's Dynamo, 1877.
This dynamo was used for many years for commercial arc lighting.

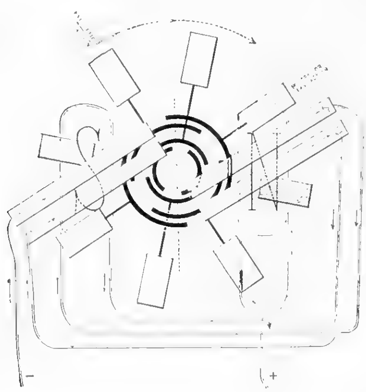
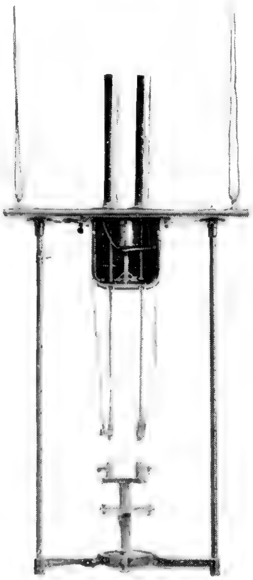


Diagram of Brush Armature.
The armature was not a closed circuit. For description of its operation, see text.

prevented undue pumping of the carbons. His dynamo had a drum-wound armature, and had several horizontal field coils on each side of one pair of poles between which the armature revolved. The system was designed for about 20 amperes, each arc taking about 35 volts.

Charles F. Brush made a very successful arc lighting system in 1878. His dynamo was unique in that the armature had eight coils, one end of each pair of opposite coils being connected together and the other ends connected to a commutator segment. Thus the armature itself was not a closed circuit. The machine had two pairs of horizontal poles between which the coils revolved. One end of the one pair of coils in the most active position was connected, by means of two of the four brushes, in series with one end of the two pairs of coils in the lesser active position. The latter two pairs of coils



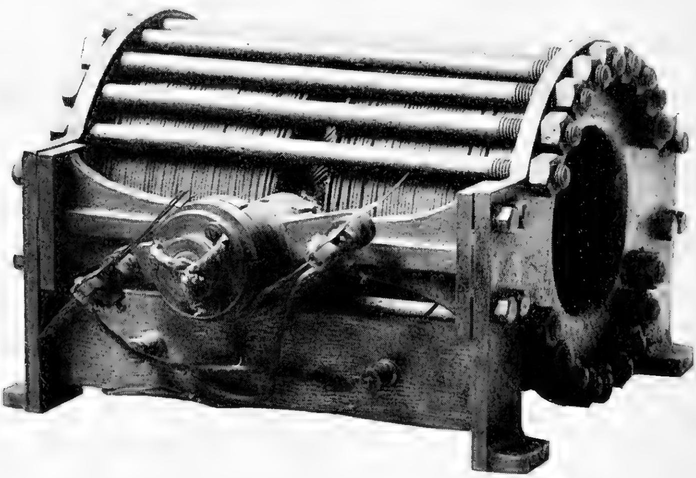
BRUSH'S ARC LAMP, 1877.

The carbons were differentially controlled. This lamp was used for many years. This lamp is in the collection of the Smithsonian Institution.

were connected in multiple with each other by means of the brushes touching adjacent commutator segments. The outside circuit was connected to the other two brushes, one of which was connected to the other end of the most active pair of coils. The other brush was connected to the other end of the two lesser active pairs of coils. The one pair of coils in the least active position was out of circuit. The field coils were connected in series with the outside circuit.

Brush's arc lamp was also differentially controlled. It was designed for about 10 amperes at about 45 volts. The carbons were copper plated to increase their conductivity. Two pairs of carbons were used for all-night service, each pair lasting about eight hours.

A very simple device was used to automatically switch the arc from one to the other pair of carbons, when the first pair was consumed. This device consisted of a triangular-shaped piece of iron connected to the solenoid controlling the arc. There was a groove on each of the outer two corners of this triangle, one groove wider than the other. An iron washer surrounded each upper carbon. The edge of each washer rested in a groove. The washer in the narrow groove made a comparatively tight fit about its carbon. The other washer in the wider groove had a loose fit about its carbon. Pins prevented the washer from falling below given points. Both pairs of carbons



THOMSON-HOUSTON ARC DYNAMO, 1878.
This dynamo was standard for many years. This machine is in the collection of the Smithsonian Institution.

touched each other at the start. When current was turned on, the solenoid lifted the triangle, the loose-fitting washer gripped its carbon first, so that current then only passed through the other pair of carbons which were still touching each other. The further movement of the solenoid then separated these carbons, the arc starting between them. When this pair of carbons became consumed, they could not feed any more so that the solenoid would then allow the other pair of carbons to touch, transferring the arc to that pair.

Elihu Thomson and Edwin J. Houston in 1878 made a very successful and complete arc light system. Their dynamo was specially designed to fit the requirements of the series arc lamp. The Thomson-Houston machine was a bipolar, having an armature consisting of three coils, one end of each of the three coils having a common terminal, or " Y " connected, as it is called. The other end of each coil was connected to a commutator segment. The machine was to a great extent self-regulating, that is the current was inherently constant with fluctuating load, as occurs when the lamps feed or when the number of lamps burning at one time should change for any reason. This regulation was accomplished by what is called " armature reaction," which is the effect the magnetization of the armature has on the field strength. Close regulation was obtained by a separate electro-magnet,

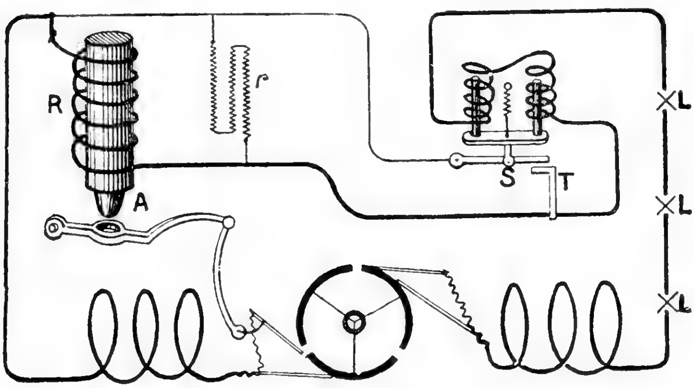


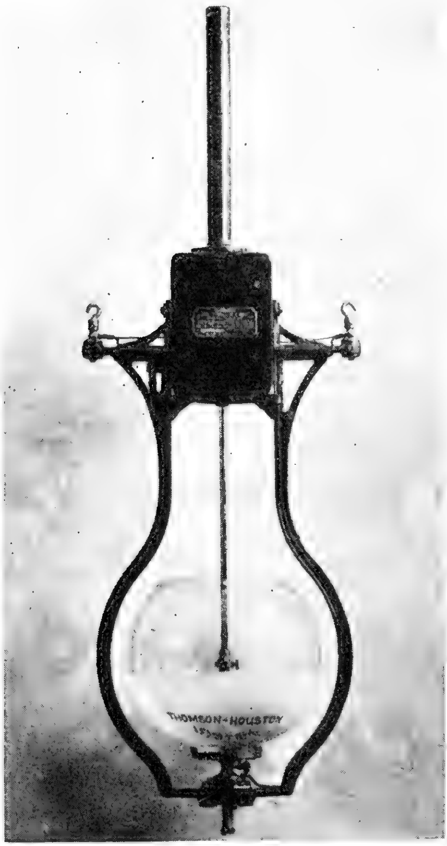
Diagram of T-H Arc Lighting System.

in series with the circuit, which shifted the brushes as the load changed. As there were but three commutator segments, one for each coil, excessive sparking was prevented by an air blast.

The " T-H " (Thompson-Houston) lamp employed the shunt feed principle. The carbons were normally separated, being in most types drawn apart by a spring. A high resistance magnet, shunted around the arc, served to draw the carbons together. This occurred on starting the lamp and thereafter the voltage of the arc was held constant by the balance between the spring and the shunt magnet. As the carbon burned away the mechanism advanced to a point where a clutch was tripped, the carbons brought together, and the cycle repeated. Both the T-H and Brush systems were extensively used in street lighting, for which they were the standard when the open arc was superseded by the enclosed.

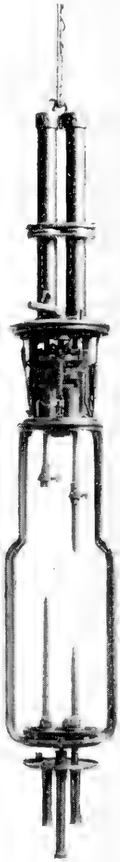
OTHER AMERICAN ARC LIGHT SYSTEMS

Beginning with about 1880, several arc light systems were developed. Among these were the Vanderpoele, Hochausen, Waterhouse, Maxim,



THOMSON-HOUSTON ARC LAMP, 1878.

This is an early model with a single pair of carbons.

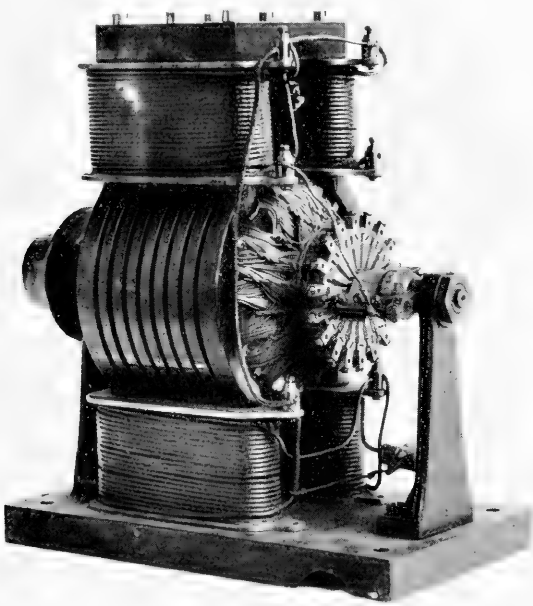


THOMSON DOUBLE CARBON ARC LAMP.

This later model, having two pairs of carbons, was commercially used for many years. This lamp is in the collection of the Smithsonian Institution.

Schuyler and Wood. The direct current carbon arc is inherently more efficient than the alternating current lamp, owing to the fact that the continuous flow of current in one direction maintains on the positive carbon a larger crater at the vaporizing point of carbon. This source furnishes the largest proportion of light, the smaller crater in the negative carbon much less. With the alternating current arc, the large crater is formed first on the upper and then on the lower carbon. On account of the cooling between alternations, the mean temperature falls below the vaporizing point of carbon, thus accounting for the lower efficiency of the alternating current arc.

For this reason all these systems used direct current and the 10 ampere ultimately displaced the 20 ampere system. The 10 ampere

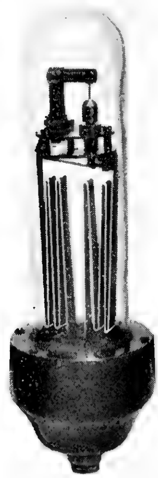


Maxim Dynamo.
This dynamo is in the collection of the Smithsonian Institution.

circuit was later standardized at 9.6 amperes, 50 volts per lamp. The lamp therefore consumed 480 watts giving an efficiency of about 15 lumens per watt. This lamp gave an average of 575 candlepower (spherical) in all directions, though it was called the 2000 cp (candlepower) arc as under the best possible conditions it could give this candlepower in one direction. Later a 6.6 ampere arc was developed. This was called the " 1200 cp " lamp and was not quite as efficient as the 9.6 ampere lamp.

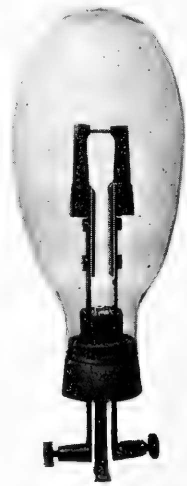
"SUB-DIVIDING THE ELECTRIC LIGHT"

While the arc lamp was being commercially established, it was at once seen that it was too large a unit for household use. Many inventors attacked the problem of making a smaller unit, or, as it was called, "sub-dividing the electric light." In the United States there were four men prominent in this work: William E. Sawyer, Moses G. Farmer, Hiram S. Maxim and Thomas A. Edison. These men did not make smaller arc lamps but all attempted to make an incandescent lamp that would operate on the arc circuits.



SAWYER'S INCANDESCENT LAMP, 1878.

This had a graphite burner operating in nitrogen gas.



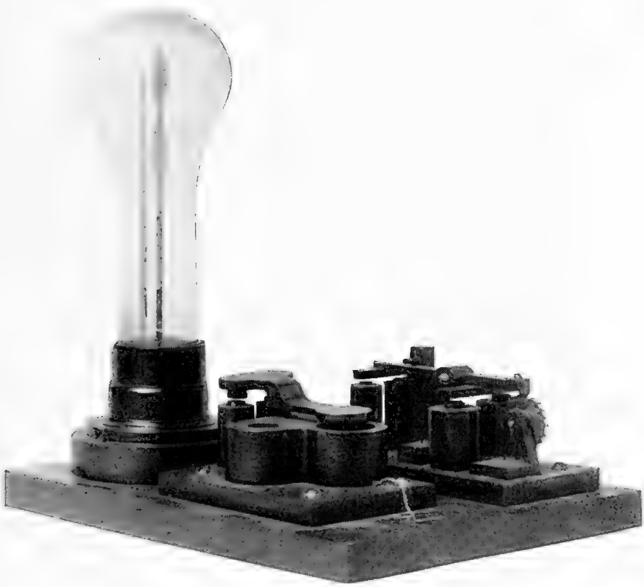
FARMER'S INCANDESCENT LAMP, 1878.

The graphite burner operated in nitrogen gas. This lamp is in the collection of the Smithsonian Institution.

Sawyer made several lamps in the years 1878-79 along the lines of the Russian scientists. All his lamps had a thick carbon burner operating in nitrogen gas. They had a long glass tube closed at one end and the other cemented to a brass base through which the gas was put in. Heavy fluted wires connected the burner with the base to radiate the heat, in order to keep the joint in the base cool. The burner was renewable by opening the cemented joint. Farmer's lamp consisted of a pair of heavy copper rods mounted on a rubber cork, between which a graphite rod was mounted. This was inserted in a glass bulb and operated in nitrogen gas. Maxim made a lamp having a carbon burner operating in a rarefied hydrocarbon vapor. He also made a lamp consisting of a sheet of platinum operating in air.

EDISON'S INVENTION OF A PRACTICAL INCANDESCENT LAMP

Edison began the study of the problem in the spring of 1878. He had a well-equipped laboratory at Menlo Park, New Jersey, with several able assistants and a number of workmen, about a hundred people all told. He had made a number of well-known inventions, among which were the quadruplex telegraph whereby four messages could be sent simultaneously over one wire, the carbon telephone transmitter without which Bell's telephone receiver would have been



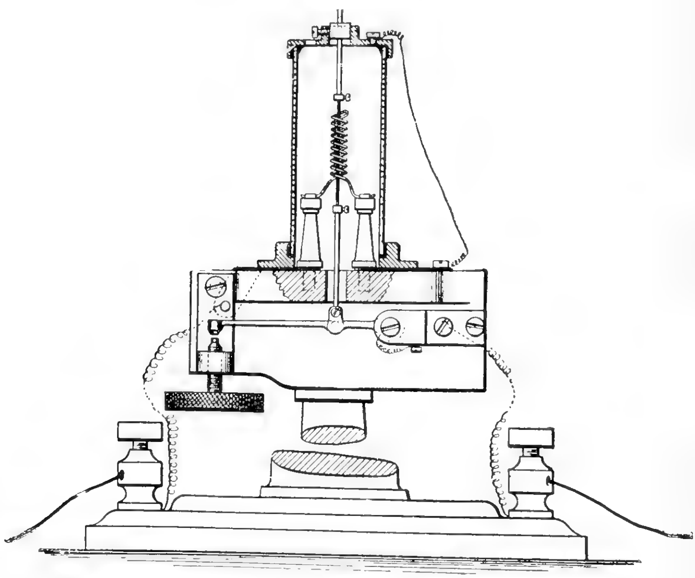
MAXIM'S INCANDESCENT LAMP, 1878.
The carbon burner operated in a rarefied hydrocarbon vapor. This lamp is in the collection of the Smithsonian Institution.

impracticable, and the phonograph. All of these are in use today, so Edison was eminently fitted to attack the problem.

Edison's first experiments were to confirm the failures of other experimenters. Convinced of the seeming impossibility of carbon, he turned his attention to platinum as a light giving element. Realizing the importance of operating platinum close to its melting temperature, he designed a lamp which had a thermostatic arrangement so that the burner would be automatically short circuited the moment its temperature became dangerously close to melting. The burner consisted of a double helix of platinum wire within which was a rod.

When the temperature of the platinum became too high, the rod in expanding would short circuit the platinum. The platinum cooled at once, the rod contracted opening the short circuit and allowing current to flow through the burner again. His first incandescent lamp patent covered this lamp. His next patent covered a similar lamp with an improved thermostat consisting of an expanding diaphragm. Both of these lamps were designed for use on series circuits.

The only system of distributing electricity, known at that time,



EDISON'S FIRST EXPERIMENTAL LAMP, 1878.
The burner was a coil of platinum wire which was protected from operating at too high a temperature by a thermostat.

was the series system. In this system current generated in the dynamo armature flowed through the field coils, out to one lamp after another over a wire, and then back to the dynamo. There were no means by which one lamp could be turned on and off without doing the same with all the others on the circuit. Edison realized that while this was satisfactory for street lighting where arcs were generally used, it never would be commercial for household lighting. He therefore decided that a practical incandescent electric lighting system must be patterned after gas lighting with which it would compete. He therefore made an intensive study of gas distribution and reasoned that a constant pressure electrical system could be made similar to that of gas.

The first problem was therefore to design a dynamo that would give a constant pressure instead of constant current. He therefore reasoned that the internal resistance of the armature must be very low or the voltage would fall as current was taken from the dynamo. Scientists had shown that the most economical use of electricity from

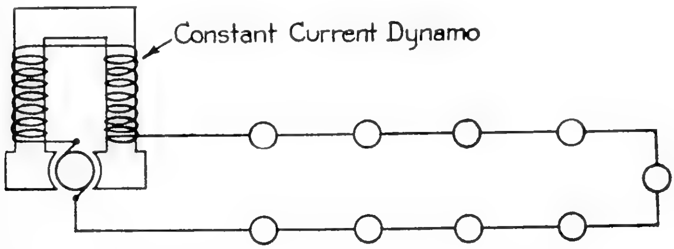


Diagram of Constant Current Series System.
This, in 1878, was the only method of distributing electric current.

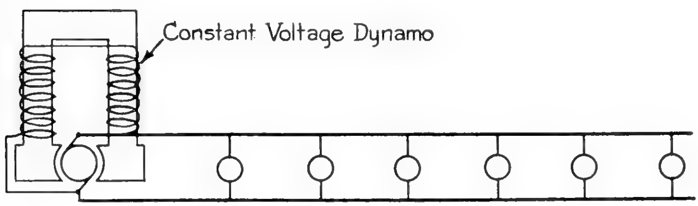
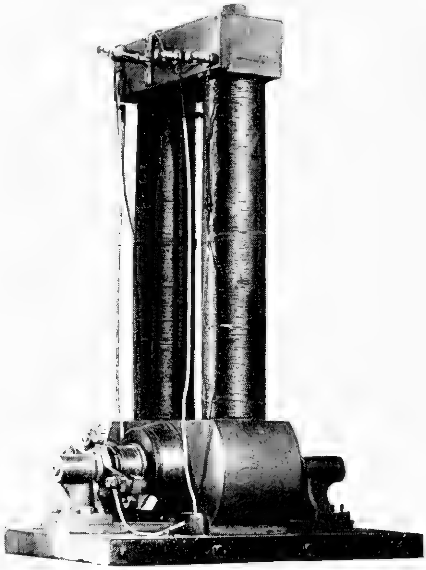


Diagram of Edison's Multiple System, 1879.
Edison invented the multiple system of distributing electric current, now universally used.

a primary battery was where the external resistance of the load was the same as the internal resistance of the battery, or in other words, 50 per cent was the maximum possible efficiency.

When Edison proposed a very low resistance armature so that the dynamo would have an efficiency of 90 per cent at full load, he was ridiculed. Nevertheless he went ahead and made one which attained this. The armature consisted of drum-wound insulated copper rods, the armature core having circular sheets of iron with paper between to reduce the eddy currents. There were two vertical fields above and connected in shunt with the armature. It generated electricity at about a hundred volts constant pressure and could supply current up to about 60 amperes at this pressure. It therefore had a capacity, in the present terminology, of about 6 kilowatts (or 8 horsepower).

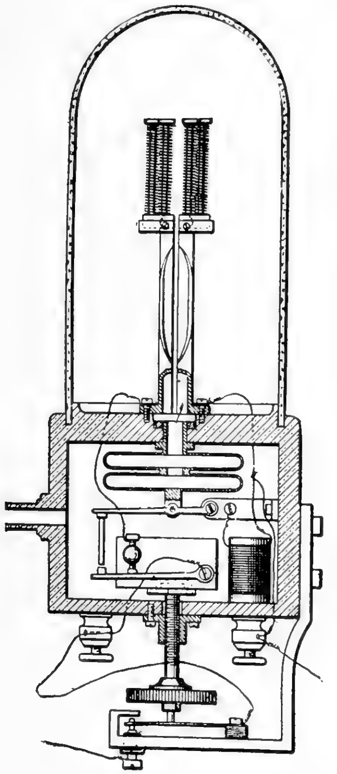
A multiple system of distribution would make each lamp independent of every other and with a dynamo made for such a system, the next thing was to design a lamp for it. Having a pressure of about



EDISON DYNAMO, 1879.

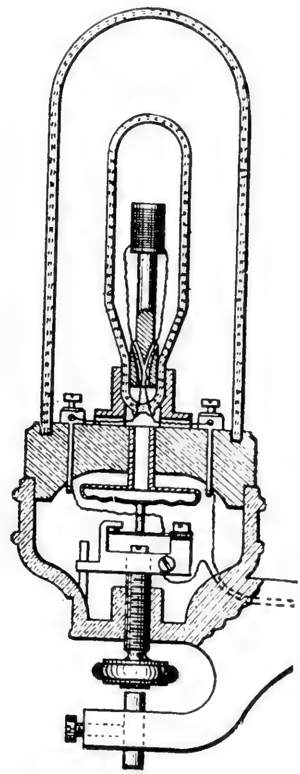
Edison made a dynamo that was 90 per cent efficient which scientists said was impossible. This dynamo is in the collection of the Smithsonian Institution and was one of the machines on the steamship Columbia, the first commercial installation of the Edison lamp.

a hundred volts to contend with, the lamp, in order to take a small amount of current, must, to comply with Ohm's law, have a high resistance. He therefore wound many feet of fine platinum wire on a spool of pipe clay and made his first high resistance lamp. He used his diaphragm thermostat to protect the platinum from melting, and, as now seems obvious but was not to all so-called electricians at that time, the thermostat was arranged to open circuit instead of short circuit the burner when it became too hot. This lamp apparently solved the problem, and, in order to protect the platinum from the oxygen of the air, he coated it with oxide of zirconium. Unfortunately zirconia, while an insulator at ordinary temperatures, becomes, as is now known, a conductor of electricity when heated, so that the lamp short circuited itself when it was lighted.



EDISON'S HIGH RESISTANCE PLATINUM LAMP, 1879.

This lamp had a high resistance burner, necessary for the multiple system.

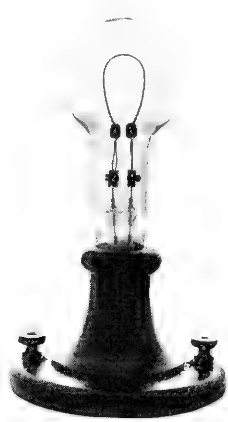


EDISON'S HIGH RESISTANCE PLATINUM IN VACUUM LAMP, 1879.

This experimental lamp led to the invention of the successful carbon filament lamp.

During his experiments he had found that platinum became exceedingly hard after it had been heated several times to incandescence by current flowing through it. This apparently raised its melting temperature so he was able to increase the operating temperature and therefore greatly increase the candlepower of his lamps after they had been heated a few times. Examination of the platinum under a microscope showed it to be much less porous after heating, so he reasoned that gases were occluded throughout the platinum and were driven out by the heat. This led him to make a lamp with a platinum wire to operate in vacuum, as he thought that more of the occluded gases would come out under such circumstances.

These lamps were expensive to make, and, knowing that he could get the requisite high resistance at much less cost from a long and



Edison's Carbon Lamp of October 21, 1879.

This experimental lamp, having a high resistance carbon filament operating in a high vacuum maintained by an all-glass globe, was the keystone of Edison's successful incandescent lighting system. All incandescent lamps made today embody the basic features of this lamp. This replica is in the Smithsonian Institution exhibit of Edison lamps. The original was destroyed.

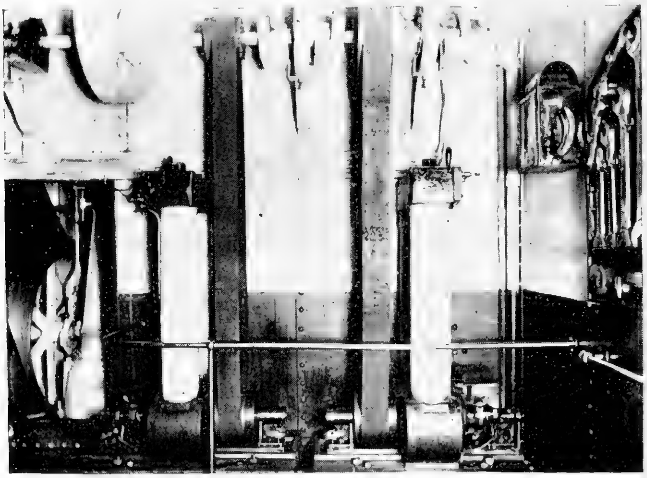
slender piece of carbon, he thought he might be able to make the carbon last in the high vacuum he had been able to obtain from the newly invented Geissler and Sprengel mercury air pumps. After several trials he finally was able to carbonize a piece of ordinary sewing thread. This he mounted in a one-piece all glass globe, all joints fused by melting the glass together, which he considered was essential in order to maintain the high vacuum. Platinum wires were fused in the glass to connect the carbonized thread inside the bulb with the circuit outside as platinum has the same coefficient of expansion as glass and hence maintains an airtight joint. He reasoned that there would be occluded gases in the carbonized thread which would immediately burn up if the slightest trace of oxygen were present, so he heated the lamp while it was still on the exhaust pump after a high degree of vacuum had been obtained. This was accomplished by passing a small amount of current through the "filament," as he called it, gently heating it. Immediately the gases started coming out, and it took eight hours more on the pump before they stopped. The lamp was then sealed and ready for trial.

On October 21, 1879, current was turned into the lamp and it lasted forty-five hours before it failed. A patent was applied for

DEMONSTRATION OF EDISON'S INCANDESCENT LIGHTING SYSTEM.
Showing view of Menlo Park Laboratory Buildings, 1880.

on November 4th of that year and granted January 27, 1880. All incandescent lamps made today embody the basic features of this lamp. Edison immediately began a searching investigation of the best material for a filament and soon found that carbonized paper gave several hundred hours life. This made it commercially possible, so in December, 1879, it was decided that a public demonstration of his incandescent lighting system should be made. Wires were run to several houses in Menlo Park, N. J., and lamps were also mounted on poles, lighting the country roads in the neighborhood. An article appeared in the New York Herald on Sunday, December 21, 1879, describing Edison's invention and telling of the public demonstration to be given during the Christmas holidays. This occupied the entire first page of the paper, and created such a furor that the Pennsylvania Railroad had to run special trains to Menlo Park to accommodate the crowds. The first commercially successful installation of the Edison incandescent lamps and lighting system was made on the steamship Columbia, which started May 2, 1880, on a voyage around Cape Horn to San Francisco, Calif.

The carbonized paper filament of the first commercial incandescent lamp was quite fragile. Early in 1880 carbonized bamboo was found to be not only sturdy but made an even better filament than paper. The shape of the bulb was also changed from round to pear shape,



Dynamo Room, S. S. Columbia.

The first commercial installation of the Edison Lamp, started May 2, 1880. One of these original dynamos is on exhibit at the Smithsonian Institution.

being blown from one inch tubing. Later the bulbs were blown directly from molten glass.

As it was inconvenient to connect the wires to the binding posts of a new lamp every time a burned out lamp had to be replaced, a base and socket for it were developed. The earliest form of base consisted simply of bending the two wires of the lamp back on the neck of the bulb and holding them in place by wrapping string around the neck. The socket consisted of two pieces of sheet copper in a hollow piece of wood. The lamp was inserted in this, the two-wire terminals of the lamp making contact with the two-sheet copper terminals of the socket, the lamp being rigidly held in the socket by a thumb screw which forced the socket terminals tight against the neck of the bulb.

This crude arrangement was changed in the latter part of 1880 to a screw shell and a ring for the base terminals, wood being used for

Original Socket for Incandescent Lamps, 1880.

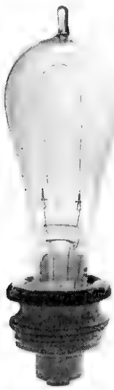
Wire Terminal Base Lamp, 1880.

This crude form of lamp base fitted the original form of lamp socket pictured above. This lamp is in the exhibit of Edison lamps in the Smithsonian Institution.

insulation. The socket was correspondingly changed. This was a very bulky affair, so the base was changed to a cone-shaped ring and a screw shell for terminals. Wood was used for insulation, which a short time after was changed to plaster of Paris as this was also used to fasten the base to the bulb. It was soon found that the tension created between the two terminals of the base when the lamp was firmly screwed in the socket often caused the plaster base to pull apart, so the shape of the base was again changed early in 1881, to the form in use today.

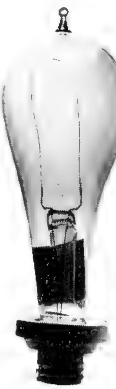
An improved method of connecting the ends of the filament to the leading-in wires was adopted early in 1881. Formerly this was accomplished by a delicate clamp having a bolt and nut. The improvement consisted of copper plating the filament to the leading-in wire.

In the early part of the year 1881 the lamps were made "eight to



ORIGINAL SCREW BASE LAMP, 1880.

This first screw base, consisting of a screw shell and ring for terminals with wood for insulation, was a very bulky affair. This lamp is in the exhibit of Edison lamps in the Smithsonian Institution.



IMPROVED SCREW BASE LAMP, 1881.

The terminals of this base consisted of a cone shaped ring and a screw shell. At first wood was used for insulation, later plaster of paris which was also used to fasten the base to the bulb. This lamp is in the exhibit of Edison lamps in the Smithsonian Institution.

the horsepower." Each lamp, therefore, consumed a little less than 100 watts, and was designed to give 16 candlepower in a horizontal direction. The average candlepower (spherical) in all directions was about 77 per cent of this, hence as the modern term "lumen" is 12.57 spherical candlepower, these lamps had an initial efficiency of about 1.7 lumens per watt. The lamps blackened considerably during their life so that just before they burned out their candlepower was less than half that when new. Thus their mean efficiency throughout life was about 1.1 l-p-w (lumens per watt). These figures are interesting in comparison with the modern 100-watt gas-filled tungsten-filament lamp which has an initial efficiency of 12.9, and a mean efficiency of 11.8, l-p-w. In other words the equivalent (wattage) size of modern lamp gives over seven times when new, and eleven times on the average, as much light for the same energy consumption as Edison's first commercial lamp. In the latter part of 1881 the efficiency was changed to "ten lamps per horsepower," equivalent to $2\frac{1}{4}$ l-p-w initially. Two sizes of lamps were made: 16 cp for use on 110-volt

FINAL FORM OF SCREW BASE, 1881.

With plaster of paris, the previous form of base was apt to pull apart when the lamp was firmly screwed into the socket. The form of the base was therefore changed to that shown, which overcame these difficulties, and which has been used ever since. The lamp shown was standard for three years and is in the exhibit of Edison lamps in the Smithsonian Institution.

circuits and 8 cp for use either direct or 55 volts or two in series on 110-volt circuits.

EDISON'S THREE-WIRE SYSTEM

The distance at which current can be economically delivered at 110 volts pressure is limited, as will be seen from a study of Ohm's law. The loss of power in the distributing wires is proportional to the square of the current flowing. If the voltage be doubled, the amount of current is halved, for a given amount of electric power delivered, so that the size of the distributing wires can then be reduced to one-quarter for a given loss in them. At that time (1881) it was impossible to make 220-volt lamps, and though they are now available, their use is uneconomical, as their efficiency is much poorer than that of 110-volt incandescent lamps.

Edison invented a distributing system that had two 110-volt circuits, with one wire called the neutral, common to both circuits so that the pressure on the two outside wires was 220 volts. The neutral wire had only to be large enough to carry the difference between the currents flowing in the two circuits. As the load could be so arranged that it would be approximately equal at all times on both circuits, the neutral wire could be relatively small in size. Thus the three-wire system resulted in a saving of 60 per cent in copper over the two-wire

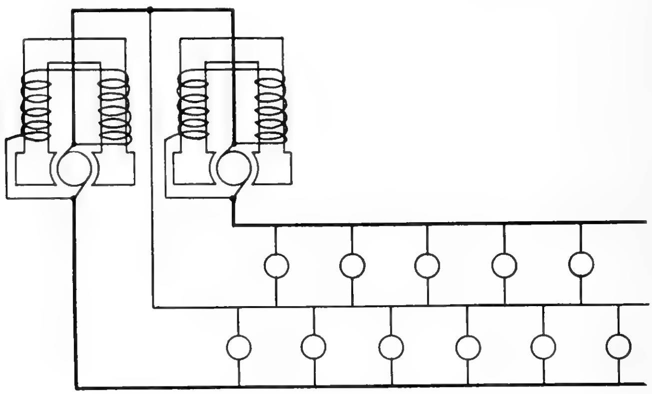


DIAGRAM OF EDISON'S THREE-WIRE SYSTEM, 1881.

This system reduced the cost of copper in the multiple distributing system 60 per cent.

system or, for the same amount of copper, the distance that current could be delivered was more than doubled.

DEVELOPMENT OF THE ALTERNATING CURRENT CONSTANT POTENTIAL SYSTEM

The distance that current can be economically distributed, as has been shown, depends upon the voltage used. If, therefore, current could be sent out at a high voltage and the pressure brought down to that desired at the various points to which it is distributed, such distribution could cover a much greater area. Lucien Gaulard was a French inventor and was backed by an Englishman named John D. Gibbs. About 1882 they patented a series alternating-current system of distribution. They had invented what is now called a transformer which consisted of two separate coils of wire mounted on an iron core. All the primary coils were connected in series, which, when current went through them, induced a current in the secondary coils. Lamps were connected in multiple on each of the secondary coils. An American patent was applied for on the transformer, but was refused on the basis that "more current cannot be taken from it than is put in." While this is true if the word energy were used, the transformer can supply a greater current at a lower voltage (or vice versa) than is put in, the ratio being in proportion to the relative number of turns in the primary and secondary coils. The transformer was treated with ridicule and Gaulard died under distressing circumstances.

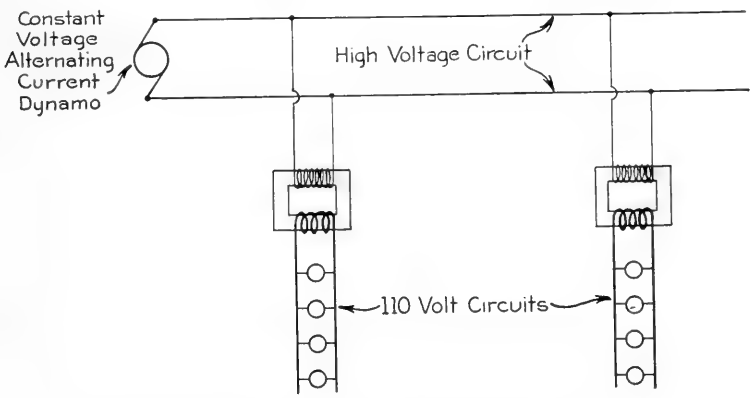


Diagram of Stanley's Alternating Current Multiple System, 1885.

This system is now universally used for distributing electric current long distances.

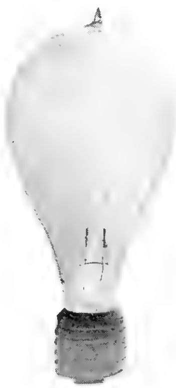
Information regarding the transformer came to the attention of William Stanley, an American, in the latter part of 1885. He made an intensive study of the scheme, and developed a transformer in which the primary coil was connected in multiple on a constant potential alternating-current high-voltage system. From the secondary coil a lower constant voltage was obtained. An experimental installation was made at Great Barrington, Mass., in the early part of 1886, the first commercial installation being made in Buffalo, New York, in the latter part of the year. This scheme enabled current to be economically distributed to much greater distances. The voltage of the high-tension circuit has been gradually increased as the art has progressed from about a thousand volts to over two hundred thousand volts pressure in a recent installation in California, where electric power is transmitted over two hundred miles.

INCANDESCENT LAMP DEVELOPMENTS, 1884-1894

In 1884 the ring of plaster around the top of the base was omitted; in 1886 an improvement was made by pasting the filament to the leading-in wires with a carbon paste instead of the electro-plating method; and in 1888 the length of the base was increased so that it had more threads. Several concerns started making incandescent lamps, the filaments being made by carbonizing various substances. "Parchmentized" thread consisted of ordinary thread passed through sulphuric acid. "Tamadine" was cellulose in the sheet form, punched

STANDARD EDISON LAMP, 1884.

The ring of plaster around the neck of previous lamps was omitted. This lamp is in the exhibit of Edison lamps in the Smithsonian Institution.

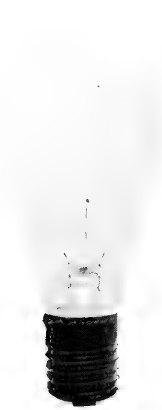


STANDARD EDISON LAMP, 1888.

The length of the base was increased so it had more threads. This lamp is in the exhibit of Edison lamps in the Smithsonian Institution.

out in the shape of the filament. Squirted cellulose in the form of a thread was also used. This was made by dissolving absorbent cotton in zinc chloride, the resulting syrup being squirted through a die into alcohol which hardened the thread thus formed. This thread was washed in water, dried in the air and then cut to proper length and carbonized.

The filament was improved by coating it with graphite. One method, adopted about 1888, was to dip it in a hydro-carbon liquid before carbonizing. Another, more generally adopted in 1893 was a process originally invented by Sawyer, one of the Americans who had attempted to "sub-divide the electric light" in 1878-79. This process consisted of passing current through a carbonized filament in an atmosphere of hydrocarbon vapor. The hot filament decomposed the vapor, depositing graphite on the filament. The graphite coated filament improved it so it could operate at 3½ lumens per watt (initial efficiency). Lamps of 20, 24, 32 and 50 candlepower were developed for 110-volt circuits. Lamps in various sizes from 12 to 36 cp were made for use on storage batteries having various numbers of cells and giving a voltage of from 20 to 40 volts. Miniature lamps of from ½ to 2 cp for use on dry batteries of from 2½ to 5½ volts, and 3 to 6 cp on

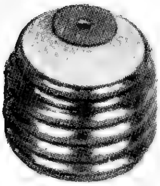


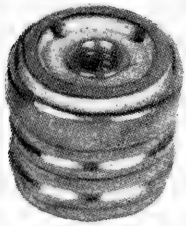
STANDARD EDISON LAMP, 1894.

This lamp had a "treated" cellulose filament, permitting an efficiency of 3½ lumens per watt which has never been exceeded in a carbon lamp. This lamp is in the exhibit of Edison lamps in the Smithsonian Institution.

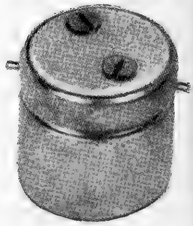
5½ to 12 volts, were also made. These could also be connected in series on 110 volts for festoons. Very small lamps of ½ cp of 2 to 4 volts for use in dentistry and surgery were made available. These miniature lamps had no bases, wires being used to connect them to the circuit.

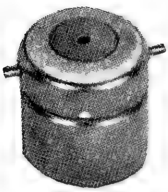
Lamps for 220-volt circuits were developed as this voltage was desirable for power purposes, electric motors being used, and a few lamps were needed on such circuits. They are less efficient and more expensive than 110-volt lamps, their use being justified however only when it is uneconomical to have a separate 110-volt circuit for lighting. The lamps were made in sizes from 16 to 50 candlepower.


Edison.


Thomson-Houston.


Westinghouse.

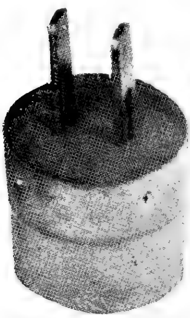

Brush-Swan.

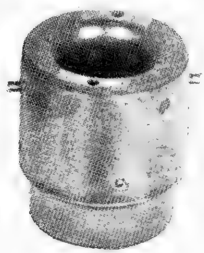

Edi-Swan
(single contact).

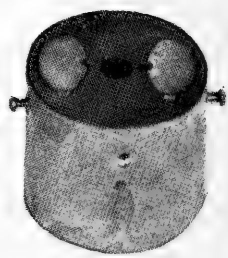

Edi-Swan
(double contact).

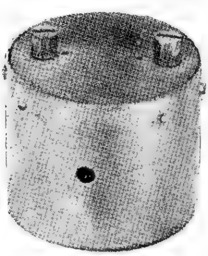

United States.

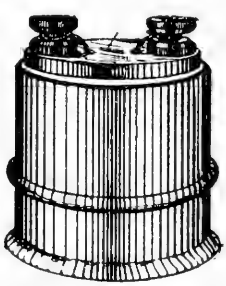

Hawkeye.

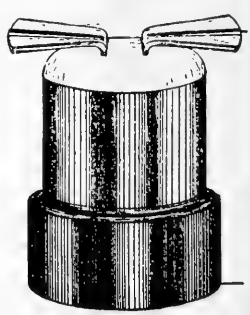

Ft. Wayne Jenny.


Mather or Perkins.

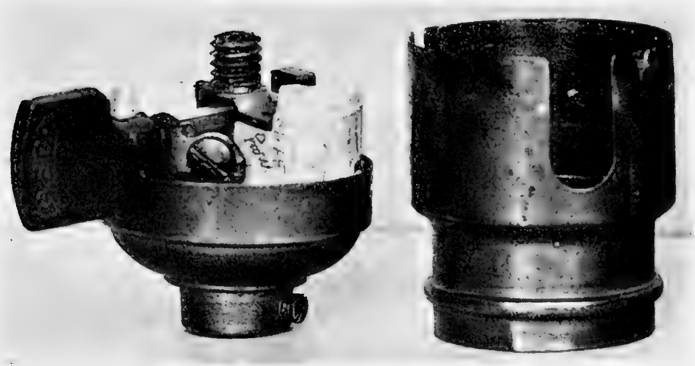

Loomis.


Schaeffer or National.

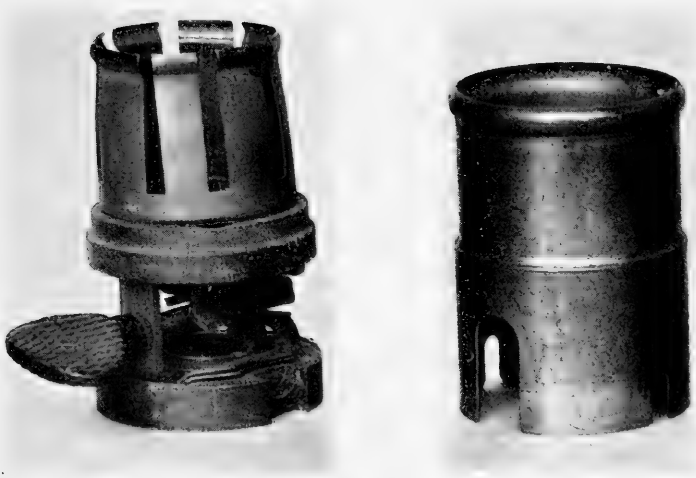

Indianapolis Jenny.


Siemens & Halske.

VARIOUS STANDARD BASES IN USE, 1892.



THOMSON-HOUSTON SOCKET.



WESTINGHOUSE SOCKET.

Electric street railway systems used a voltage in the neighborhood of 550, and lamps were designed to burn five in series on this voltage. These lamps were different from the standard 110-volt lamps although they were made for about this voltage. As they were burned in series, the lamps were selected to operate at a definite current instead of at a definite voltage, so that the lamps when burned in series would operate at the proper temperature to give proper life results. Such lamps would therefore vary considerably in individual volts, and hence would not give good service if burned on 110-volt circuits. The candelabra screw base and socket and the miniature screw base and socket were later developed. Ornamental candelabra base lamps

Thomson-Houston.

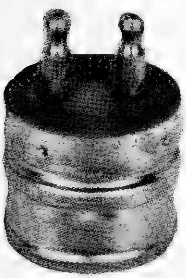
Westinghouse.

Adapters for Edison Screw Sockets, 1892.

Next to the Edison base, the Thomson-Houston and Westinghouse bases were the most popular. By use of these adapters, Edison base lamps could be used in T-H and Westinghouse sockets.

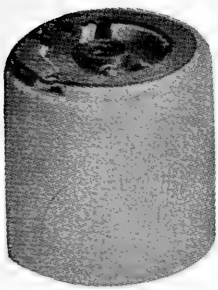
were made for use direct on 110 volts, smaller sizes being operated in series on this voltage. The former gave about 10 cp, the latter in various sizes from 4 to 8 cp. The miniature screw base lamps were for low volt lighting.

The various manufacturers of lamps in nearly every instance made bases that were very different from one another. No less than fourteen different standard bases and sockets came into commercial use. These were known as, Brush-Swan, Edison, Edi-Swan (double contact), Edi-Swan (single contact), Fort Wayne Jenny, Hawkeye, Indianapolis Jenny, Loomis, Mather or Perkins, Schaeffer or National, Siemens & Halske, Thomson-Houston, United States and Westinghouse. In addition there were later larger sized bases made for use on series circuits. These were called the Bernstein, Heisler, Large Edison, Municipal Bernstein, Municipal Edison, Thomson-Houston (alternating circuit) and Thomson-Houston (arc circuit). Some of these bases disappeared from use and in 1900 the proportion in the United States was about 70 per cent Edison, 15 per cent West-

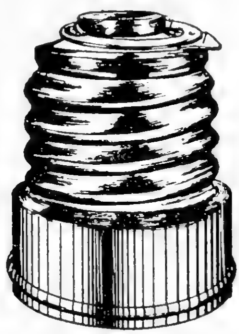

Bernstein.


Heisler.


Thomson-Houston
(alternating current).


Thomson-Houston
(arc circuit).


Municipal Edison.


Municipal Bernstein.

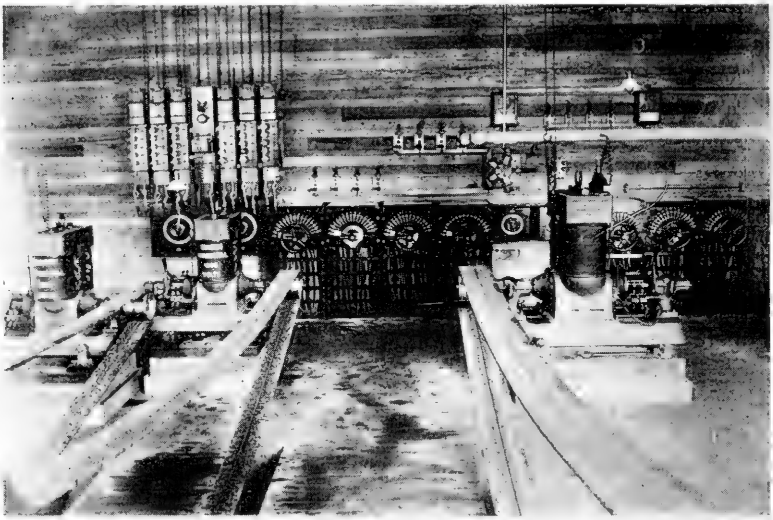
VARIOUS SERIES BASES IN USE, 1892.

The above six bases have been superseded by the "Large Edison," now called the Mogul Screw base.

inghouse, 10 per cent Thomson-Houston and 5 per cent for all the others remaining. A campaign was started to standardize the Edison base, adapters being sold at cost for the Westinghouse and Thomson-Houston sockets so that Edison base lamps could be used. In a few years the desired results were obtained so that now there are no other sockets in the United States but the Edison screw type for standard lighting service. This applies also to all other countries in the world except England where the bayonet form of base and socket is still popular.

THE EDISON "MUNICIPAL" STREET LIGHTING SYSTEM

The arc lamp could not practically be made in a unit smaller than the so-called "1200 candlepower" (6.6 ampere) or "half" size, which really gave about 350 spherical candlepower. A demand there-

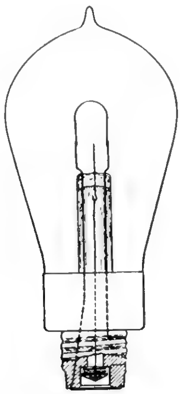


EDISON "MUNICIPAL" SYSTEM, 1885.

High voltage direct current was generated, several circuits operating in multiple, three ampere lamps burning in series on each circuit. Photograph courtesy of Association of Edison Illuminating Companies.

fore arose for a small street lighting unit, and Edison designed his "Municipal" street lighting system to fill this requirement. His experience in the making of dynamos enabled him to make a direct current bipolar constant potential machine that would deliver 1000 volts which later was increased to 1200 volts. They were first made in two sizes having an output of 12 and 30 amperes respectively. Incandescent lamps were made for 3 amperes in several sizes from 16 to 50 candlepower. These lamps were burned in series on the 1200-volt direct current system. Thus the 12-ampere machine had a capacity for four series circuits, each taking 3 amperes, the series circuits being connected in multiple across the 1200 volts. The number of lamps on each series circuit depended upon their size, as the voltage of each lamp was different for each size, being about 1½ volts per cp.

A popular size was the 32-candlepower unit, which therefore required about 45 volts and hence at 3 amperes consumed about 135 watts. Allowing 5 per cent loss in the wires of each circuit, there was therefore 1140 of the 1200 volts left for the lamps. Hence about 25 32-candlepower or 50 16-candlepower lamps could be put on each series circuit. Different sizes of lamps could also be put on the



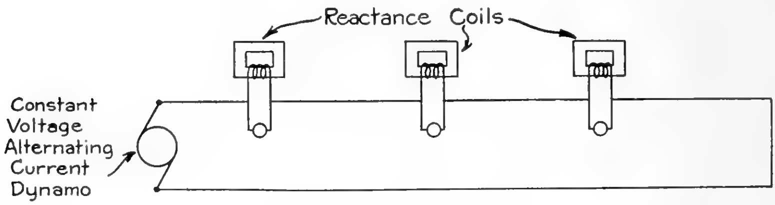
Edison Municipal Lamp, 1885.
Inside the base was an arrangement by which the lamp was automatically short circuited when it burned out.

same circuit, the number depending upon the aggregate voltage of the lamps.

A device was put in the base of each lamp to short circuit the lamp when it burned out so as to prevent all the other lamps on that circuit from going out. This device consisted of a piece of wire put inside the lamp bulb between the two ends of the filament. Connected to this wire was a very thin wire inside the base which held a piece of metal compressed against a spring. The spring was connected to one terminal of the base. Should the lamp burn out, current would jump from the filament to the wire in the bulb, and the current then flowed through the thin wire to the other terminal of the base. The thin wire was melted by the current, and the spring pushed the piece of metal up short circuiting the terminals of the base. This scheme was later simplified by omitting the wire, spring, etc., and substituting a piece of metal which was prevented from short circuiting the terminals of the base by a thin piece of paper. When the lamp burned out the entire 1200 volts was impressed across this piece of paper, puncturing it and so short circuiting the base terminals. Should one or more lamps go out on a circuit, the increase in current above the normal 3 amperes was prevented by an adjustable resistance, or an extra lot of lamps which could be turned on one at a time, connected to each circuit and located in the power station under the control of the operator. This system disappeared from use with the advent of the constant current transformer.

THE SHUNT BOX SYSTEM FOR SERIES INCANDESCENT LAMPS

Soon after the commercial development of the alternating current constant potential system, a scheme was developed to permit the use



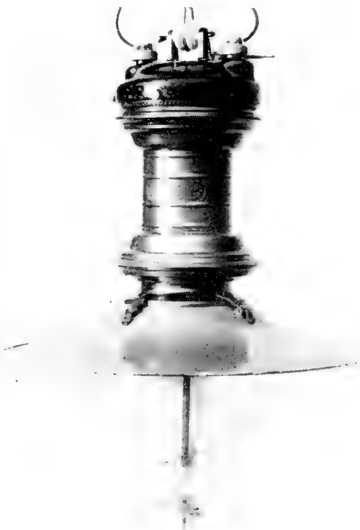
Shunt Box System, 1887.

Lamps were burned in series on a high voltage alternating current, and when a lamp burned out all the current then went through its "shunt box," a reactance coil in multiple with each lamp.

of lamps in series on such circuits without the necessity for short circuiting a lamp should it burn out. A reactance, called a "shunt box" and consisting of a coil of wire wound on an iron core, was connected across each lamp. The shunt box consumed but little current while the lamp was burning. Should one lamp go out, the entire current would flow through its shunt box and so maintain the current approximately constant. It had the difficulty, however, that if several lamps went out, the current would be materially increased tending to burn out the remaining lamps on the circuit. This system also disappeared from use with the development of the constant current transformer.

THE ENCLOSED ARC LAMP

Up to 1893 the carbons of an arc lamp operated in the open air, so that they were rapidly consumed, lasting from eight to sixteen hours depending on their length and thickness. Louis B. Marks, an American, found that by placing a tight fitting globe about the arc, the life of the carbons was increased ten to twelve times. This was due to the restricted amount of oxygen of the air in the presence of the hot carbon tips and thus retarded their consumption. The amount of light was somewhat decreased, but this was more than offset by



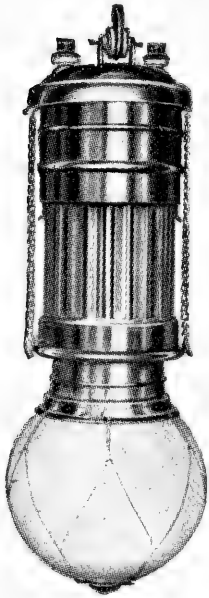
Enclosed Arc Lamp, 1893.
Enclosing the arc lengthened the life of the carbons, thereby greatly reducing the cost of maintenance.

the lesser expense of trimming which also justified the use of more expensive better quality carbons. Satisfactory operation required that the arc voltage be increased to about 80 volts.

This lamp rapidly displaced the series open arc. An enclosed arc lamp for use on 110-volt constant potential circuits was also developed. A resistance was put in series with the arc for use on 110-volt direct current circuits, to act as a ballast in order to prevent the arc from taking too much current and also to use up the difference between the arc voltage (80) and the line voltage (110). On alternating current, a reactance was used in place of the resistance.

The efficiencies in lumens per watt of these arcs (with clear glassware), all of which have now disappeared from the market, were about as follows:

6.6 ampere 510 watt direct current (D. C.) series arc, $8\frac{1}{4}$ l-p-w.
5.0 ampere 550 watt direct current multiple (110-volt) arc, $4\frac{1}{2}$ l-p-w.
7.5 ampere 540 watt alternating current (A. C.) multiple (110-volt) arc, $4\frac{1}{4}$ l-p-w.



Open Flame Arc Lamp, 1898.

Certain salts impregnated in the carbons produced a brilliantly luminous flame in the arc stream which enormously increased the efficiency of the lamp.

Enclosed Flame Arc Lamp, 1908.

By condensing the smoke from the arc in a cooling chamber it was practical to enclose the flame arc, thereby increasing the life of the carbons.

The reason for the big difference in efficiency between the series and multiple direct-current arc is that in the latter a large amount of electrical energy (watts) is lost in the ballast resistance. While there is a considerable difference between the inherent efficiencies of the D. C. and A. C. arcs themselves, this difference is reduced in the multiple D. C. and A. C. arc lamps as more watts are lost in the resistance ballast of the multiple D. C. lamp than are lost in the reactance ballast of the multiple A. C. lamp.

This reactance gives the A. C. lamp what is called a "power-factor." The product of the amperes (7.5) times the volts (110) does not give the true wattage (540) of the lamp, so that the actual volt-amperes (825) has to be multiplied by a power factor, in this case about 65 per cent, to obtain the actual power (watts) consumed. The reason is that the instantaneous varying values of the alternating current and pressure, if multiplied and averaged throughout the complete alternating cycle, do not equal the average amperes (measured by an ammeter) multiplied by the average voltage (measured by a voltmeter). That is, the maximum value of the current flowing (amperes) does not occur at the same instant that the maximum pressure (voltage) is on the circuit.

THE FLAME ARC LAMP

About 1844 Bunsen investigated the effect of introducing various chemicals in the carbon arc. Nothing was done, however, until Bremer, a German, experimented with various salts impregnated in the carbon electrodes. In 1898 he produced the so-called flame arc, which consisted of carbons impregnated with calcium fluoride. This gave a brilliant yellow light most of which came from the arc flame, and practically none from the carbon tips. The arc operated in the open air and produced smoke which condensed into a white powder.

The two carbons were inclined downward at about a 30-degree angle with each other, and were of small diameter but long, 18 to 30 inches, having a life of about 12 to 15 hours. The tips of the carbons projected through an inverted earthenware cup, called the "economizer," the white powder condensing on this and acting not only as an excellent reflector but making a dead air space above the arc. The arc was maintained at the tips of the carbons by an electromagnet whose magnetic field "blew" the arc down.

Two flame arc lamps were burned in series on 110-volt circuits. They consumed 550 watts each, giving an efficiency of about 35 lumens per watt on direct current. On alternating current the efficiency was about 30 l-p-w. By use of barium salts impregnated in the carbons, a white light was obtained, giving an efficiency of about 18 l-p-w on direct current and about 15½ on alternating current. These figures cover lamps equipped with clear glassware. Using strontium salts in the carbons, a red light was obtained at a considerably lower efficiency, such arcs on account of their color being used only to a limited extent for advertising purposes.

These arcs were remarkably efficient but their maintenance expense was high. Later, about 1908, enclosed flame arcs with vertical carbons

Constant Current Transformer, 1900.
This converted alternating current of constant voltage into constant current, for use on series circuits.

were made which increased the life of the carbons, the smoke being condensed in cooling chambers. However, their maintenance expense was still high. They have now disappeared from the market, having been displaced by the very efficient gas-filled tungsten filament incandescent lamp which appeared in 1913.

THE CONSTANT CURRENT TRANSFORMER FOR SERIES CIRCUITS

About 1900 the constant current transformer was developed by Elihu Thomson. This transforms current taken from a constant potential alternating current circuit into a constant alternating current for series circuits, whose voltage varies with the load on the circuit. The transformer has two separate coils; the primary being stationary and connected to the constant potential circuit and the secondary being movable and connected to the series circuit. The weight of the secondary coil is slightly underbalanced by a counter weight. Current flowing in the primary induces current in the secondary, the two coils repelling each other. The strength of the repelling force depends upon the amount of current flowing in the two coils. The core of the transformer is so designed that the central part, which the two coils surround, is magnetically more powerful close to the primary coil than it is further away.

When the two coils are close together a higher voltage is induced in the secondary than if the later were further away from the primary coil. In starting, the two coils are pulled apart by hand to prevent too large a current flowing in the series circuit. The secondary coil is allowed to gradually fall and will come to rest at a point where the voltage induced in it produces the normal current in the series circuit, the repelling force betwen the two coils holding the secondary at this point. Should the load in the series circuit change for any reason, the current in the series circuit would also change, thus changing the force repelling the two coils. The secondary would therefore move until the current in the series circuit again becomes normal. The action is therefore automatic, and the actual current in the series circuit can be adjusted within limits to the desired amount, by varying the counterweight. A dash pot is used to prevent the secondary coil from oscillating (pumping) too much.

In the constant current transformer, the series circuit is insulated from the constant potential circuit. This has many advantages. A similar device, called an automatic regulating reactance was developed which is slightly less expensive, but it does not have the advantage of insulating the two circuits from each other.

ENCLOSED SERIES ALTERNATING CURRENT ARC LAMPS

The simplicity of the constant current transformer soon drove the constant direct-current dynamo from the market. An enclosed arc lamp was therefore developed for use on alternating constant current.

Two sizes of lamps were made; one for 6.6 amperes consuming 450 watts and having an efficiency of about 4½ lumens per watt, and the other 7.5 amperes, 480 watts and 5 l-p-w (clear glassware). These lamps soon superseded the direct current series arcs. They have now been superseded by the more efficient magnetite arc and tungsten filament incandescent lamps.

SERIES INCANDESCENT LAMPS ON CONSTANT CURRENT TRANSFORMERS

Series incandescent lamps were made for use on constant current transformers superseding the "Municipal" and "Shunt Box" systems. The large Edison, now called the Mogul Screw base, was adopted and the short circuiting film cut-out was removed from the base and placed between prongs attached to the socket.

Holder.

Socket.

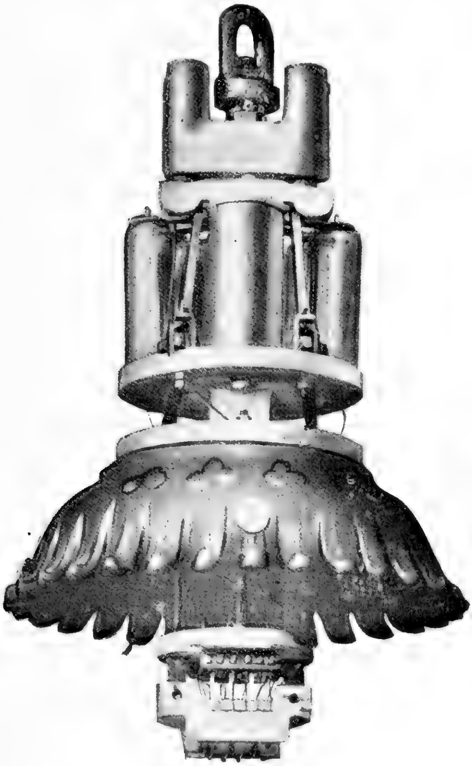
Holder and socket.

SERIES INCANDESCENT LAMP SOCKET WITH FILM CUTOUT, 1900.
The "Large Edison," now called Mogul Screw, base was standardized and the short circuiting device put on the socket terminals.

The transformers made for the two sizes of arc lamps, produced 6.6 and 7.5 amperes and incandescent lamps, in various sizes from 16 to 50 cp, were made for these currents so that the incandescent lamps could be operated on the same circuit with the arc lamps. The carbon series incandescent lamp, however, was more efficient if made for lower currents, so 3½-, 4- and 5½-ampere constant current transformers were made for incandescent lamps designed for these amperes. Later, however, with the advent of the tungsten filament, the 6.6-ampere series tungsten lamp was made the standard, as it was slightly more efficient than the lower current lamps, and was made in sizes from 32 to 400 cp. When the more efficient gas-filled tungsten lamps were developed, the sizes were further increased; the standard 6.6-ampere lamps now made are from 60 to 2500 cp.

THE NERNST LAMP

Dr. Walther Nernst, of Germany, investigating the rare earths used in the Welsbach mantle, developed an electric lamp having a burner, or "glower" as it was called, consisting of a mixture of these oxides.



NERNST LAMP, 1900.
The burners consisted mainly of zirconium oxide which had to be heated before current could go through them.

The main ingredient was zirconia, and the glower operated in the open air. It is a non-conductor when cold, so had to be heated before current would flow through it. This was accomplished by an electric heating coil, made of platinum wire, located just above the glower. As the glower became heated and current flowed through it, the heater was automatically disconnected by an electro-magnet cut-out.

The resistance of the glower decreases with increase in current, so a steadying resistance was put in series with it. This consisted of an iron wire mounted in a bulb filled with hydrogen gas and was called a "ballast." Iron has the property of increasing in resistance with increase in current flowing through it, this increase being very marked between certain temperatures at which the ballast was operated. The lamp was put on the American market in 1900 for use on 220-volt alternating current circuits. The glower consumed 0.4 ampere. One, two, three, four and six glower lamps were made, consuming 88, 196, 274, 392 and 528 watts respectively. As most of the light is thrown downward, their light output was generally given in mean lower hemispherical candlepower. The multiple glower lamps were

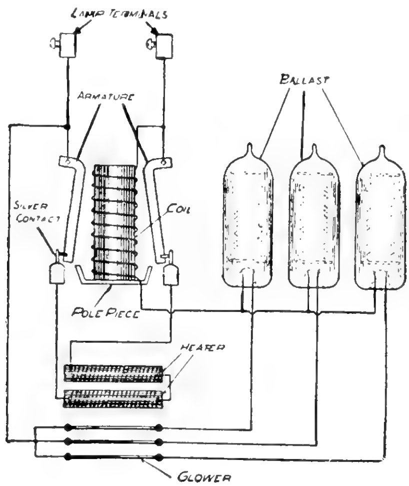
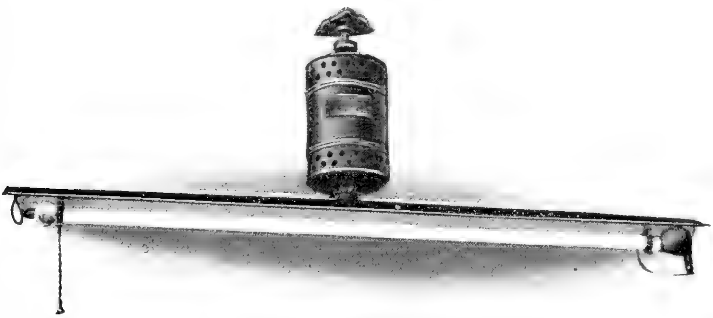


Diagram of Nernst Lamp.

more efficient than the single glower, owing to the heat radiated from one glower to another. Their efficiencies, depending on the size, were from about 3½ to 5 lumens per watt, and their average candlepower throughout life was about 80 per cent of initial. The lamp disappeared from the market about 1912.

THE COOPER-HEWITT LAMP

In 1860 Way discovered that if an electric circuit was opened between mercury contacts a brilliant greenish colored arc was produced. Mercury was an expensive metal and as the carbon arc seemed to give the most desirable results, nothing further was done for many years until Dr. Peter Cooper Hewitt, an American, began experimenting with it. He finally produced an arc in vacuum in a one-inch glass tube about 50 inches long for 110 volts direct current circuits, which was commercialized in 1901. The tube hangs at about 15 degrees from the horizontal. The lower end contains a small quantity of mercury. The terminals are at each end of the tube, and the arc was first started by tilting the tube by hand so that a thin stream of mercury bridged the two terminals. Current immediately vaporized the mercury, starting the arc. A resistance is put in series with the arc to maintain the current constant on direct current constant voltage circuits. Automatic starting devices were later developed, one of which consisted of an electro-magnet that tilted the lamp, and the other of an induction coil giving a high voltage which, in discharging, started the arc.



COOPER-HEWITT MERCURY VAPOR ARC LAMP, 1901.
This gives a very efficient light, practically devoid of red but of high actinic value, so useful in photography.

This lamp is particularly useful in photography on account of the high actinic value of its light. Its light is very diffused and is practically devoid of red rays, so that red objects appear black in its light. The lamp consumes $3\frac{1}{2}$ amperes at 110 volts direct current (385 watts) having an efficiency of about $12\frac{1}{2}$ lumens per watt.

The mercury arc is peculiar in that it acts as an electric valve tending to let current flow through it only in one direction. Thus on alternating current, the current impulses will readily go through it in one direction, but the arc will go out in the other half cycle unless means are taken to prevent this. This is accomplished by having two terminals at one end of the tube, which are connected to choke coils, which in turn are connected to a single coil (auto) transformer. The alternating current supply mains are connected to wires tapping different parts of the coil of the auto transformer. The center of the coil of the auto transformer is connected through an induction coil to the other end of the tube. By this means the alternating current impulses are sent through the tube in one direction, one half cycle from one of the pairs of terminals of the tube, the other half cycle from the other terminal. Thus pulsating direct current, kept constant by the induction coil, flows through the tube, the pulsations overlapping each other by the magnetic action of the choke coils. This alternating current lamp is started by the high voltage discharge method. It has a 50-inch length of tube, consuming about 400 watts

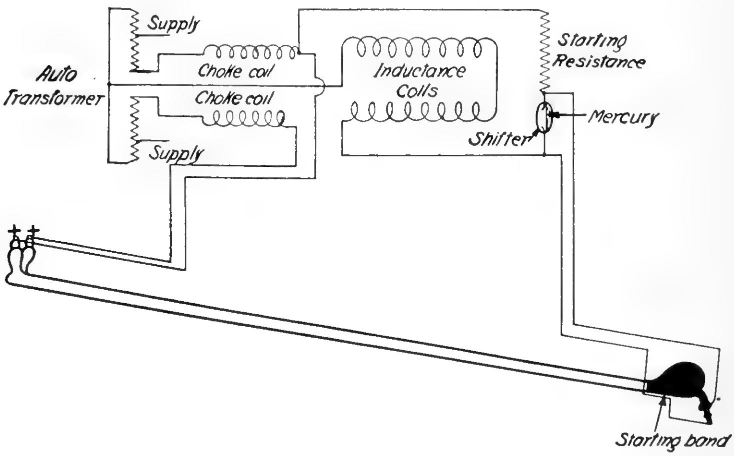


Diagram of Cooper-Hewitt Lamp for Use on Alternating Current.

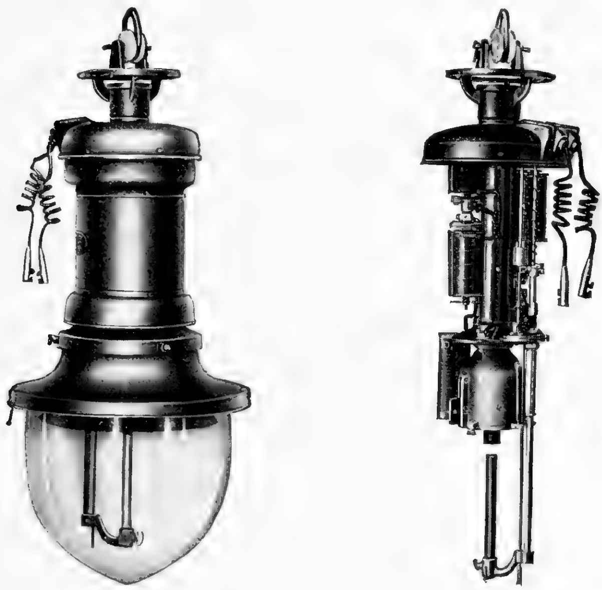
The mercury arc is inherently for use on direct current, but by means of reactance coils, it can be operated on alternating current.

on 110 volts. Its efficiency is a little less than that of the direct current lamp.

THE LUMINOUS OR MAGNETITE ARC LAMP

About 1901 Dr. Charles P. Steinmetz, Schenectady, N. Y., studied the effect of metallic salts in the arc flame. Dr. Willis R. Whitney, also of Schenectady, and director of the research laboratory of the organization of which Dr. Steinmetz is the consulting engineer, followed with some further work along this line. The results of this work were incorporated in a commercial lamp called the magnetite arc lamp, through the efforts of C. A. B. Halvorson, Jr., at Lynn, Mass. The negative electrode consists of a pulverized mixture of magnetite (a variety of iron ore) and other substances packed tightly in an iron tube. The positive electrode is a piece of copper sheathed in iron to prevent oxidization of the copper. The arc flame gives a brilliant white light, and, similar to the mercury arc, is inherently limited to direct current. It burns in the open air at about 75 volts. The lamp is made for 4-ampere direct current series circuits and consumes about 310 watts and has an efficiency of about 11½ lumens per watt.

The negative (iron tube) electrode now has a life of about 350



Luminous or Magnetite Arc Lamp, 1902.
This has a negative electrode containing magnetite which produces a very luminous white flame in the arc stream.

hours. Later, a higher efficiency, 4-ampere electrode was made which has a shorter life but gives an efficiency of about 17 l-p-w, and a 6.6-ampere lamp was also made giving an efficiency of about 18 l-p-w using the regular electrode. This electrode in being consumed gives off fumes, so the lamp has a chimney through its body to carry them off. Some of the fumes condense, leaving a fine powder, iron oxide, in the form of rust. The consumption of the positive (copper) electrode is very slow, which is opposite to that of carbon arc lamps on direct current. The arc flame is brightest near the negative (iron tube) electrode and decreases in brilliancy and volume as it nears the positive (copper) electrode.

The peculiarities of the arc are such that Halvorson invented an entirely new principle of control. The electrodes are normally apart. In starting, they are drawn together by a starting magnet with sufficient force to dislodge the slag which forms on the negative electrode

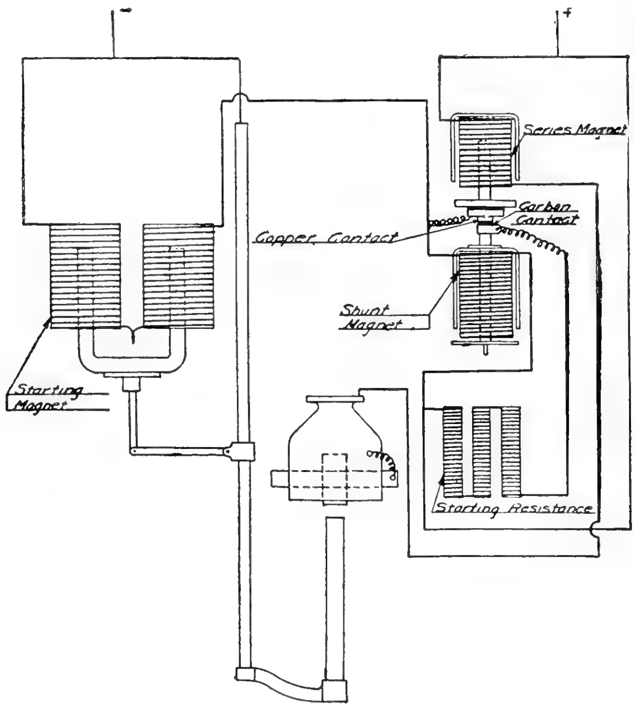


Diagram of Series Magnetite Arc Lamp.

The method of control, entirely different from that of other arc lamps, was invented by Halvorson to meet the peculiarities of this arc.

and which becomes an insulator when cold. Current then flows through the electrodes and through a series magnet which pulls up a solenoid breaking the circuit through the starting magnet. This allows the lower electrode to fall a fixed distance, about seven-eighths of an inch, drawing the arc, whose voltage is then about 72 volts. As the negative electrode is consumed, the length and voltage of the arc increases when a magnet, in shunt with the arc, becomes sufficiently energized to close the contacts in the circuit of the starting magnet causing the electrode to pick up and start off again.

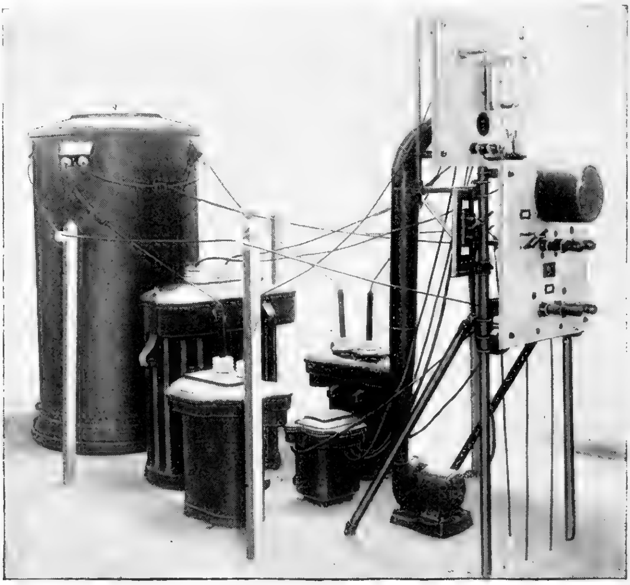
MERCURY ARC RECTIFIER FOR MAGNETITE ARC LAMPS

As the magnetite arc requires direct current for its operation, the obvious way to supply a direct constant current for series circuits is to rectify, by means of the mercury arc, the alternating current ob-

MERCURY ARC RECTIFIER TUBE FOR SERIES MAGNETITE ARC LAMPS, 1902.

The mercury arc converted the alternating constant current into direct current required by the magnetite lamp.

tained from a constant current transformer. The terminals of the movable secondary coil of the constant current transformer are connected to the two arms of the rectifier tube. One end of the series circuit is connected to the center of the secondary coil. The other end of the series circuit is connected to a reactance which in turn is connected to the pool of mercury in the bottom of the rectifier tube. One-half of the cycle of the alternating current goes from the secondary coil to one arm of the rectifier tube through the mercury vapor, the mercury arc having already been started by a separate starting electrode. It then goes to the pool of mercury, through the reactance and through the series circuit. The other half cycle of alternating current goes to the other arm of the rectifier tube, through the mercury vapor, etc., and through the series circuit. Thus a pulsating direct current flows through the series circuit, the magnetic action of the reactance coil making the pulsations of current overlap each other, which prevents the mercury arc from going out.



Early Mercury Arc Rectifier Installation.

INCANDESCENT LAMP DEVELOPMENTS, 1894-1904

With the development of a waterproof base in 1900, by the use of a waterproof cement instead of plaster of Paris to fasten the base to the bulb, porcelain at first and later glass being used to insulate the terminals of the base from each other, lamps could be exposed to the weather and give good results. Electric sign lighting therefore received a great stimulus, and lamps as low as 2 candlepower for 110 volts were designed for this purpose. Carbon lamps with concentrated filaments were also made for stereoptican and other focussing purposes. These lamps were made in sizes from 20 to 100 candlepower. The arc lamp was more desirable for larger units.

The dry battery was made in small units of 2, 3 and 5 cells, so that lamps of about $\frac{1}{8}$ to 1 candlepower were made for $2\frac{1}{2}$, $3\frac{1}{2}$ and $6\frac{1}{2}$ volts, for portable flashlights. It was not however until the tungsten filament was developed in 1907 that these flashlights became as popular as they now are. For ornamental lighting, lamps were supplied in round and tubular bulbs, usually frosted to soften the light.

THE MOORE TUBE LIGHT, 1904.

This consisted of a tube about 1¾ inches in diameter and having a length up to 200 feet, in which air at about one thousandth part of atmospheric pressure was made to glow by a very high voltage alternating current.

THE MOORE TUBE LIGHT

Geissler, a German, discovered sixty odd years ago, that a high voltage alternating current would cause a vacuum tube to glow. This light was similar to that obtained by Hawksbee over two hundred years ago. Geissler obtained his high voltage alternating current by a spark coil, which consisted of two coils of wire mounted on an iron core. Current from a primary battery passed through the primary coil, and this current was rapidly interrupted by a vibrator on the principle of an electric bell. This induced an alternating current of high voltage in the secondary coil as this coil had a great many more turns than the primary coil had. Scientists found that about 70 per cent of the electrical energy put into the Geissler tube was converted into the actual energy in the light given out.

In 1891 Mr. D. McFarlan Moore, an American, impressed with the fact that only one-half of one per cent of the electrical energy put into the carbon-incandescent lamp came out in the form of light, decided to investigate the possibilities of the vacuum tube. After several years of experiments and the making of many trial lamps,

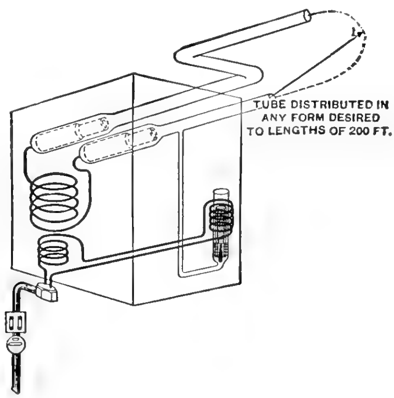


Diagram of Feeder Valve of Moore Tube.

As the carbon terminals inside the tube absorbed the very slight amount of gas in the tube, a feeder valve allowed gas to flow in the tube, regulating the pressure to within one ten thousandth part of an atmosphere above and below the normal extremely slight pressure required.

he finally, in 1904, made a lamp that was commercially used in considerable numbers.

The first installation of this form of lamp was in a hardware store in Newark, N. J. It consisted of a glass tube 1¾ inches in diameter and 180 feet long. Air, at a pressure of about one-thousand part of an atmosphere, was in the tube, from which was obtained a pale pink color. High voltage (about 16,000 volts) alternating current was supplied by a transformer to two carbon electrodes inside the ends of the tube. The air had to be maintained within one ten-thousandth part of atmospheric pressure above and below the normal of one-thousandth, and as the rarefied air in the tube combined chemically with the carbon electrodes, means had to be devised to maintain the air in the tube at this slight pressure as well as within the narrow limits required.

This was accomplished by a piece of carbon through which the air could seep, but if covered with mercury would make a tight seal. As the air pressure became low, an increased current would flow through the tube, the normal being about a tenth of an ampere. This accordingly increased the current flowing through the primary coil of the transformer. In series with the primary coil was an electro-magnet which lifted, as the current increased, a bundle of iron wires mounted in a glass tube which floated in mercury. The glass tube, rising, lowered the height of the mercury, uncovering a carbon rod cemented in a tube connecting the main tube with the open air. Thus air could seep through this carbon rod until the proper amount was fed into the main tube. When the current came back to normal the electro-magnet lowered the floating glass tube which raised the height of the mercury and covered the carbon rod, thus shutting off the further supply of air.

As there was a constant loss of about 400 watts in the transformer, and an additional loss of about 250 watts in the two electrodes, the total consumption of the 180-foot tube was about 2250 watts. Nitrogen gas gave a yellow light, which was more efficient and so was later used. On account of the fixed losses in the transformer and electrodes the longer tubes were more efficient, though they were made in various sizes of from 40 to 200 feet. The 200-foot tube, with nitrogen, had an efficiency of about 10 lumens per watt. Nitrogen gas was supplied the tube by removing the oxygen from the air used. This was accomplished by passing the air over phosphorous which absorbed the oxygen.

Carbon dioxide gas (CO_2) gave a pure white light but at about half the efficiency of nitrogen. The gas was obtained by allowing hydrochloric acid to come in contact with lumps of marble (calcium carbonate) which set free carbon dioxide and water vapor. The latter was absorbed by passing the gas through lumps of calcium chloride. The carbon dioxide tube on account of its daylight color value, made an excellent light under which accurate color matching could be done. A short tube is made for this purpose and this is the only use which the Moore tube now has, owing to the more efficient and simpler tungsten filament incandescent lamp.

THE OSMIUM LAMP

Dr. Auer von Welsbach, the German scientist who had produced the Welsbach gas mantle, invented an incandescent electric lamp having a filament of the metal osmium. It was commercially introduced in Europe in 1905 and a few were sold, but it was never marketed in this country. It was generally made for 55 volts, two lamps to burn in series on 110-volt circuits, gave about 25 candlepower and had an initial efficiency of about $5\frac{1}{2}$ lumens per watt. It had a very fair maintenance of candlepower during its life, having an average efficiency of about 5 l-p-w. Osmium is a very rare and

Osmium Lamp, 1905.

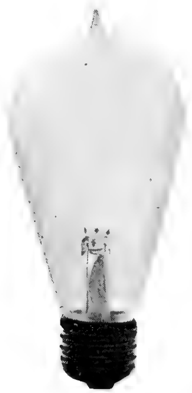
This incandescent lamp was used in Europe for a few years, but was impractical to manufacture in large quantities as osmium is rarer and more expensive than platinum.

expensive metal, usually found associated with platinum, and is therefore very difficult to obtain. Burnt out lamps were therefore bought back in order to obtain a supply of osmium. It is also a very brittle metal, so that the lamps were extremely fragile.

THE GEM LAMP

Dr. Willis R. Whitney, of Schenectady, N. Y., had invented an electrical resistance furnace. This consisted of a hollow carbon tube, packed in sand, through which a very heavy current could be passed. This heated the tube to a very high temperature, the sand preventing the tube from oxidizing, so that whatever was put inside the tube could be heated to a very high heat. Among his various experiments, he heated some carbon filaments and found that the high temperature changed their resistance "characteristic" from negative to positive. The ordinary carbon filament has a resistance when hot that is less than when it is cold, which was reversed after heating it to the high temperature Dr. Whitney was able to obtain. These filaments were made into lamps for 110-volt service and it was found that they could be operated at an efficiency of 4 lumens per watt. The lamps also blackened less than the regular carbon lamp throughout their life.

This lamp was put on the market in 1905 and was called the Gem or metallized carbon filament lamp as such a carbon filament had a



Gem Lamp, 1905.

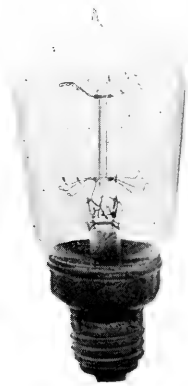
This incandescent lamp had a graphitized carbon filament obtained by the heat of an electric furnace, so that it could be operated at 25 per cent higher efficiency than the regular carbon lamp. This lamp is in the exhibit of Edison lamps in the Smithsonian Institution.

resistance characteristic similar to metals. At first it had two single hair pin filaments in series which in 1909 were changed to a single loop filament like the carbon lamp.

In 1905 the rating of incandescent lamps was changed from a candlepower to a wattage basis. The ordinary 16-candlepower carbon lamp consumed 50 watts and was so rated. The 50-watt Gem lamp gave 20 candlepower, both candlepower ratings being their mean candlepower in a horizontal direction. The Gem lamp was made for 110-volt circuits in sizes from 40 to 250 watts. The 50-watt size was the most popular, many millions of which were made before the lamp disappeared from use in 1918. The lamp was not quite as strong as the carbon lamp. Some Gem lamps for series circuits were also made, but these were soon superseded by the tungsten-filament lamp which appeared in 1907.

THE TANTALUM LAMP

Dr. Werner von Bolton, a German physicist, made an investigation of various materials to see if any of them were more suitable than carbon for an incandescent-lamp filament. After experimenting with various metals, tantalum was tried. Tantalum had been known to science for about a hundred years. Von Bolton finally obtained some of the pure metal and found it to be ductile so that it could be drawn



TANTALUM LAMP, 1906.

The tantalum filament could be operated at 50 per cent greater efficiency than that of the regular carbon incandescent lamp. This lamp is in the exhibit of Edison lamps in the Smithsonian Institution.

out into a wire. As it had a low specific resistance, the wire filament had to be much longer and thinner than the carbon filament. A great number of experimental lamps were made so that it was not until 1906 that the lamp was put on the market in this country. It had an initial efficiency of 5 lumens per watt and a good maintenance of candle power throughout its life, having an average efficiency of about $4\frac{1}{4}$ l-p-w. The usual sizes of lamps were 40 and 80 watts giving about 20 and 40 candlepower respectively. It was not quite as strong as the carbon lamp, and on alternating current the wire crystallized more rapidly, so that it broke more easily, giving a shorter life than on direct current. It disappeared from use in 1913.

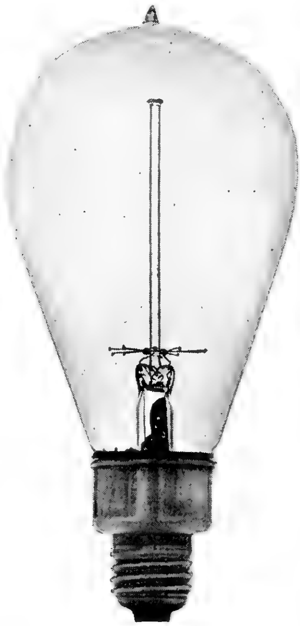
INVENTION OF THE TUNGSTEN LAMP

Alexander Just and Franz Hanaman in 1902 were laboratory assistants to the Professor of Chemistry in the Technical High School in Vienna. Just was spending his spare time in another laboratory in Vienna, attempting to develop a boron incandescent lamp. In August of that year he engaged Hanaman to aid him in his work. They conceived the idea of making a lamp with a filament of tungsten and for two years worked on both lamps. The boron lamp turned out to be a failure. Their means were limited; Hanaman's total income was $44 per month and Just's was slightly more than this. In 1903 they took out a German patent on a tungsten filament, but the process they described was a failure because it produced a filament containing both carbon and tungsten. The carbon readily evaporated and quickly blackened the bulb when they attempted to operate the filament at an efficiency higher than that possible with the ordinary carbon filament. Finally in the latter part of the next year (1904) they were able to get rid of the carbon and produced a pure tungsten filament.

Tungsten had been known to chemists for many years by its compounds, its oxides and its alloys with steel, but the properties of the pure metal were practically unknown. It is an extremely hard and brittle metal and it was impossible at that time to draw it into a wire. Just and Hanaman's process of making a pure tungsten filament consisted of taking tungsten oxide in the form of an extremely fine powder, reducing this to pure tungsten powder by heating it while hydrogen gas passed over it. The gas combined with the oxygen of the oxide, forming water vapor which was carried off, leaving the tungsten behind.

The tungsten powder was mixed with an organic binding material, and the paste was forced by very high pressure through a hole drilled in a diamond. This diamond die was necessary because tungsten, being so hard a substance, would quickly wear away any other kind of die. The thread formed was cut into proper lengths, bent the shape of a hair pin and the ends fastened to clamps. Current was passed through the hair pin in the presence of hydrogen gas and water vapor. The current heated the hair pin, carbonized the organic binding material in it, the carbon then combining with the moist hydrogen gas, leaving the tungsten particles behind. These particles were sintered together by the heat, forming the tungsten filament. Patents were applied for in various countries, the one in the United States on July 6, 1905.

The two laboratory assistants in 1905 finally succeeded in getting their invention taken up by a Hungarian lamp manufacturer. By the end of the year lamps were made that were a striking success for they could be operated at an efficiency of 8 lumens per watt. They were put on the American market in 1907, the first lamp put out being the 100-watt size for 110-volt circuits. This was done by mounting several hair pin loops in series to get the requisite resistance, tungsten having a low specific resistance. The issue of the American patent

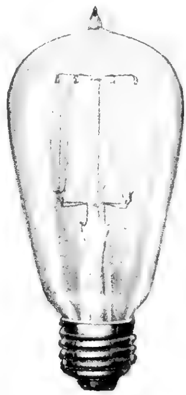


TUNGSTEN LAMP, 1907.

The original 100 watt tungsten lamp was nearly three times as efficient as the carbon lamp, but its "pressed" filament was very fragile. This lamp is in the exhibit of Edison lamps in the Smithsonian Institution.

was delayed owing to an interference between four different parties, each claiming to be the inventor. After prolonged hearings, one application having been found to be fraudulent, the patent was finally granted to Just and Hanaman on February 27, 1912.

This "pressed" tungsten filament was quite fragile, but on account of its relatively high efficiency compared with other incandescent lamps, it immediately became popular. Soon after its introduction it became possible to make finer filaments so that lamps for 60, 40 and then 25 watts for 110-volt circuits were made available. Sizes up to 500 watts were also made which soon began to displace the enclosed carbon arc lamp. Lamps were also made for series circuits in sizes from 32 to 400 candlepower. These promptly displaced the carbon and Gem series lamps. The high efficiency of the tungsten filament was a great stimulus to flashlights which are now sold by the millions each year. The lighting of railroad cars, Pullmans and coaches, with tungsten lamps obtaining their current from storage batteries, soon superseded the gas light formerly used. In some cases, a dynamo, run by a belt from the car axle, kept these batteries charged.



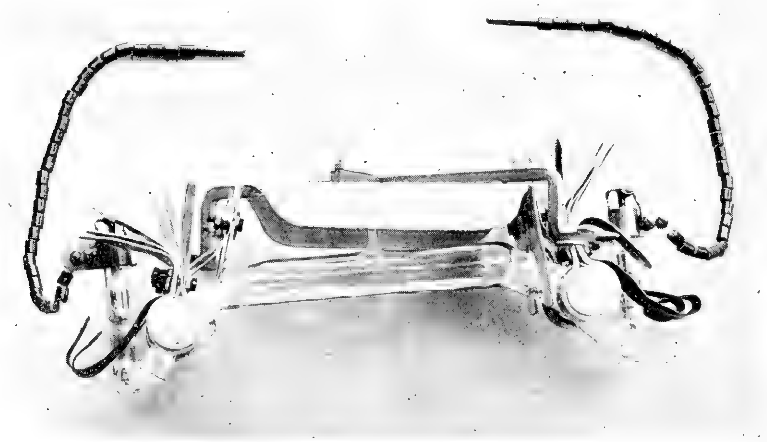
Drawn Tungsten Wire Lamp, 1911.

Scientists had declared it impossible to change tungsten from a brittle to ductile metal. This, however, was accomplished by Dr. Coolidge, and drawn tungsten wire made the lamp very sturdy. This lamp is in the exhibit of Edison lamps in the Smithsonian Institution.

DRAWN TUNGSTEN WIRE

After several years of patient experiment, Dr. William D. Coolidge in the research laboratory of a large electrical manufacturing company at Schenectady, N. Y., invented a process for making tungsten ductile, a patent for which was obtained in December, 1913. Tungsten had heretofore been known as a very brittle metal, but by means of this process it became possible to draw it into wire. This greatly simplified the manufacture of lamps and enormously improved their strength. Such lamps were commercially introduced in 1911.

With drawn tungsten wire it was easier to coil and therefore concentrate the filament as required by focusing types of lamps. The automobile headlight lamp was among the first of these, which in 1912 started the commercial use of electric light on cars in place of oil and acetylene gas. On street railway cars the use of tungsten lamps, made possible on this severe service by the greater sturdiness of the drawn wire, greatly improved their lighting. Furthermore, as the voltage on street railway systems is subject to great changes, the candlepower of the tungsten filament has the advantage of varying but about half as much as that of the carbon lamp on fluctuating voltage.



QUARTZ MERCURY VAPOR LAMP, 1912.

The mercury arc if enclosed in quartz glass can be operated at much higher temperature and therefore greater efficiency. The light is still deficient in red but gives a considerable amount of ultra violet rays which kill bacteria and are very dangerous to the eye. They can, however, be absorbed by a glass globe. The lamp is not used as an illuminant in this country, but is valuable for use in the purification of water.

THE QUARTZ MERCURY VAPOR ARC LAMP

By putting a mercury arc in a tube made of quartz instead of glass, it can be operated at a much higher temperature and thereby obtain a greater efficiency. Such a lamp, however, is still largely deficient in red rays, and it gives out a considerable amount of ultra-violet rays. These ultra-violet rays will kill bacteria and the lamp is being used to a certain extent for such purpose as in the purification of water. These rays are very dangerous to the eyes, but they are absorbed by glass, so as an illuminant, a glass globe must be used on the lamp. These lamps appeared in Europe about 1912 but were never used to any extent in this country as an illuminant. They have an efficiency of about 26 lumens per watt. Quartz is very difficult to work, so the cost of a quartz tube is very great. The ordinary bunsen gas flame is used with glass, but quartz will only become soft in an oxy-hydrogen or oxy-acetylene flame.

GAS FILLED TUNGSTEN LAMP, 1913.

By operating a coiled filament in an inert gas, Dr. Langmuir was able to greatly increase its efficiency, the gain in light by the higher temperature permissible, more than offsetting the loss of heat by convection of the gas. This lamp is in the exhibit of Edison lamps in the Smithsonian Institution.

THE GAS-FILLED TUNGSTEN LAMP

The higher the temperature at which an incandescent lamp filament can be operated, the more efficient it becomes. The limit in temperature is reached when the material begins to evaporate rapidly, which blackens the bulb. The filament becoming thinner more quickly, thus rupturing sooner, shortens the life. If, therefore, the evaporating temperature can by some means be slightly raised, the efficiency will be greatly improved. This was accomplished by Dr. Irving Langmuir in the research laboratories at Schenectady, N. Y., by operating a tungsten filament in an inert gas. Nitrogen was first used. The gas circulating in the bulb has the disadvantage of conducting heat away from the filament so that the filament was coiled. This presented a smaller surface to the currents of gas and thereby reduced this loss. The lamps were commercially introduced in 1913 and a patent was granted in April, 1916.

An increased amount of electrical energy is required in these lamps to offset the heat being conducted away by the gas. This heat loss is minimized in a vacuum lamp, the filament tending to stay hot on the principle of the vacuum bottle. This loss in a gas filled lamp becomes relatively great in a filament of small diameter, as the surface in proportion to the volume of the filament increases with decreasing diam-

Gas Filled Tungsten Lamp, 1923.

This is the form of the lamp as at present made. For 110-volt circuits the sizes range from 50 to 1000 watts.

eters. Hence there is a point where the gain in temperature is offset by the heat loss. The first lamps made were of 750 and 1000 watts for 110-volt circuits. Later 500- and then 400-watt lamps were made. The use of argon gas, which has a poorer heat conductivity than nitrogen, made it possible to produce smaller lamps, 50-watt gas-filled lamps for 110-volt circuits now being the smallest available. In the present state of the art, a vacuum lamp is more efficient than a gas-filled lamp having a filament smaller than one consuming about half an ampere. Thus gas-filled lamps are not now practicable much below 100 watts for 220 volts, 50 watts for 110 volts, 25 watts for 60 volts, 15 watts for 30 volts, etc.

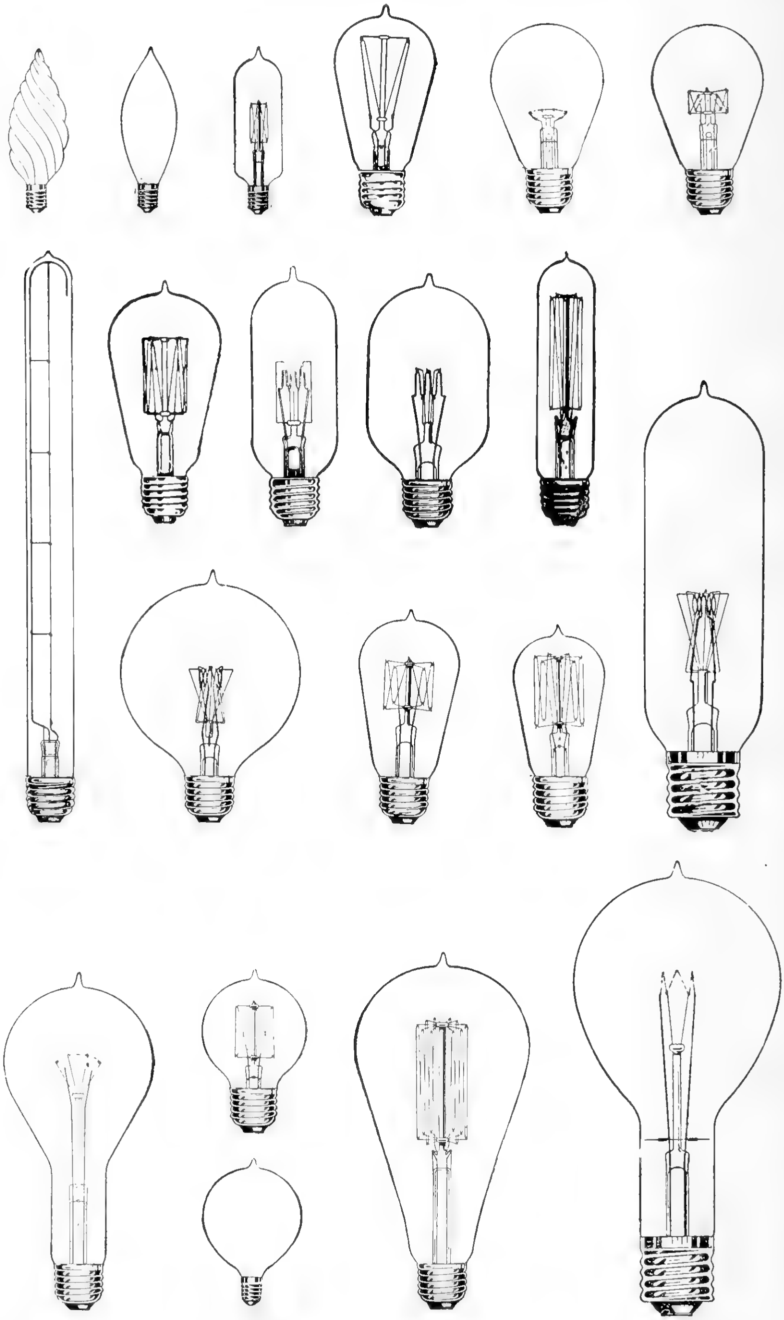
From the foregoing it will be seen that the efficiency of these lamps depends largely on the diameter of the filament. There are other considerations, which also apply to vacuum lamps, that affect the efficiency. Some of these are: the number of anchors used, as they conduct heat away; in very low voltage lamps having short filaments the relative amount of heat conducted away by the leading-in wires becomes of increasing importance, etc. The 1000-watt lamp for 110-volt circuits is now made for nearly 20½ lumens per watt; the 50-watt lamp a little over 10 l-p-w.

The advent of the tungsten filament and especially the gas-filled lamp sounded the doom of all other electric illuminants except the magnetite and mercury arc lamps. All other incandescent lamps have now practically disappeared. The flame arc as well as the enclosed carbon arc lamp are hardly ever seen. The simplicity of the incandescent lamp, its cleanliness, low first cost, low maintenance cost and high efficiency of the tungsten filament have been the main reasons for its popularity.

TYPES AND SIZES OF TUNGSTEN LAMPS NOW MADE

There are about two hundred different types and sizes of tungsten filament lamps now standard for various kinds of lighting service. For 110-volt service, lamps are made in sizes from 10 to 1000 watts. Of the smaller sizes, some are made in round and tubular-shaped bulbs for ornamental lighting. In addition there are the candelabra lamps used in ornamental fixtures. Twenty-five- to five hundred-watt lamps are made with bulbs of special blue glass to cut out the excess of red and yellow rays and thus produce a light approximating daylight.

For 220-volt service lamps are made in sizes of from 25 to 1000 watts. For sign lighting service, 5-watt lamps of low voltage are made for use on a transformer located near the sign to reduce the 110 volts alternating current to that required by the lamps. Lamps are made from 5 to 100 watts for 30-volt service, such as is found in train lighting and in gas engine driven dynamo sets used in rural homes beyond the reach of central station systems. Concentrated filament lamps are made for stereopticon and motion picture projection, floodlighting, etc., in sizes from 100 to 1000 watts, for street railway headlights in sizes below 100 watts and for locomotive headlights in sizes from 100 to 250 watts. For series circuits, used in street lighting, lamps are made from 60 to 2500 candlepower. Miniature lamps cover those for flashlight, automobile, Christmas-tree, surgical and dental services, etc. They range, depending on the service, from ½ to 21 candlepower, and in voltage from 2½ to 24.



STANDARD TUNGSTEN LAMPS, 1923.

This illustrates some of the two hundred different lamps regularly made.

STANDARD VOLTAGES

Mention has been made of 110-volt service, 220-volt service, etc. In the days of the carbon incandescent lamp it was impossible to manufacture all lamps for an exact predetermined voltage. The popular voltage was 110, so lighting companies were requested in a number of instances to adjust their service to some voltage other than 110. They were thus able to utilize the odd voltage lamps manufactured, and this produced a demand for lamps of various voltages from 100 to 130. Arc lamps had a resistance (reactance on alternating current) that was adjustable for voltages between 100 and 130.

Similarly a demand was created for lamps of individual voltages of from 200 to 260. The 200- to 260-volt range has simmered down to 220, 230, 240 and 250 volts. These lamps are not as efficient as the 110-volt type and their demand is considerably less, as the 110-volt class of service for lighting is, with the exception of England, almost universal. Thus 110-volt service means 100 to 130 volts in contra-distinction to 200 to 260 volts, etc. The drawn tungsten wire filament made it possible to accurately predetermine the voltage of the lamp, so now that the carbon incandescent lamp is a thing of the past, there is no need for so many different voltages. Several years ago standard voltages of 110, 115 and 120 were recommended for adoption by all the electrical societies in the United States, and practically all central stations have now changed their service to one of these voltages.

COST OF INCANDESCENT ELECTRIC LIGHT

In the early '80's current was expensive, costing a consumer on the average about twenty cents per kilowatt hour. The cost has gradually come down and the general average rate for which current is sold for lighting purposes is now about 4½ cents. During the period 1880 to 1905 the average efficiency of carbon lamps throughout their life increased from about one to over 2¾ lumens per watt and their list price decreased from one dollar to twenty cents. The average amount of light obtained for one cent at first was about five candlepower hours and in 1904 it was increased to over thirty-six at the average rate then in effect. The next year with the more efficient Gem lamp 44 candle-hours could be had for one cent. In 1906 the amount was increased to 50 with the tantalum lamp and with the tungsten lamp in 1907, even at its high price of $1.50, the amount was further increased to 63. Since then the average cost of current has been reduced but slightly, but the efficiency of the tungsten lamp has materially increased and its cost reduced so that it is now possible to obtain, with the ordinary 40-watt lamp 170 candle-hours for a cent. If the gas-filled tungsten lamp were used the amount of light now obtained for a cent would depend upon the size, which, for the 1000-watt lamp, would be 382 candle-hours.

STATISTICS REGARDING THE PRESENT DEMAND FOR LAMPS

In the United States there are about 350 million incandescent and about two hundred thousand magnetite arc lamps now (1923) in use. They are increasing about 10 per cent each year. The annual demand for incandescent lamps for renewals and new installations is over 200 millions, exclusive of miniature lamps. The use of incandescent lamps in all other countries put together is about equal that in the U. S.

The average candlepower of standard lighting lamps has increased from 16, which prevailed during the period prior to 1905, to over 60. The average wattage has not varied much during the past twenty-odd years, the average lamp now consuming about 55 watts. This indicates that the public is utilizing the improvement in lamp efficiency by increased illumination. The present most popular lamp is the 40-watt size which represents 20 per cent of the total demand. Second in demand is the 25-watt at 18 per cent and third, the 50-watt at 15 per cent of the total in numbers. While the aggregate demand of all the gas-filled tungsten lamps is a little over 20 per cent in numbers, they represent, on account of their greater efficiency and wattage, over half the amount of total candlepower used. In the United States about 85 per cent of all lamps are for the 110-volt range. About 5 per cent for 220 volts, 2 per cent for street series lighting, 3 per cent for street railway and 5 per cent for trainlighting and miscellaneous classes of service.

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SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 76, NUMBER 3

ON THE FOSSIL CRINOID FAMILY CATILLOCRINIDAE

(WITH FIVE PLATES)

BY

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(PUBLICATION 2718)

CITY OF WASHINGTON

PUBLISHED BY THE SMITHSONIAN INSTITUTION

AUGUST 3, 1923

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

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CONTENTS

HISTORICAL INTRODUCTION

In connection with studies upon the Inadunate division of the fossil crinoids, I have from time to time made notes upon a number of rare or little known forms of which our knowledge has been increased by discoveries made since the time of the original descriptions. One of these is the singular type placed by Wachsmuth and Springer (Revision of the Palaeocrinoidae, pt. 3, 1886, p. 267) under the family name Catillocrinidae—highly specialized, and widely differentiated from other known forms, although evident lines of descent leading to it have been pointed out by Bather in 1893 and 1900, and by Jaekel in 1895.

As originally defined, the family consisted of only two genera, from the Devonian and the Lower Carboniferous, of Europe and America respectively. It is now increased by a third, described by Professor Wanner from the island of Timor, by which the geographic range of this peculiar crinoid type is enormously extended, and, if the present determination of its horizon as Permian should stand, its occurrence is brought down to a far later age than was before suspected.

The chief development of the type embraced in this family took place in the genus *Catillocrinus,* from the American Lower Carboniferous, through which it has an almost unbroken stratigraphic range in a succession of six species, admitting of interesting comparative studies. It was recognized by the pioneer geologist and paleontologist, Troost, in the course of researches covering a period of fifteen years ending in 1849, when he proposed the name of the genus with its type species, *C. tennesseeae,* in a "List of the Crinoids of Tennessee," read at the meeting of the American Association for Advancement of Science for that year, and published in the Proceedings under date of 1850. As the "List" was not accompanied by any descriptions, the names were without validity; some were validated through subsequent publication by other authors, with credit to Troost, but many of them were superseded and lost. Troost prepared a monograph containing full descriptions and figures of his crinoid genera and species, for which he was never able to secure publication, and which remained in the MS stage until 1909, when it was issued by the National Museum as Bulletin 64, edited by Miss Elvira Wood.

The description on which the genus and its type species must rest for their names and validity is that of Shumard, published in his Catalogue of Paleozoic Fossils, St. Louis, 1866, p. 358. It was based upon specimens from Button Mould Knob in Kentucky; but the author had seen the specimens used by Troost, obtained at White's Creek Springs, Tennessee, and he credited Troost with the names of the genus and species, but made the descriptions according to his own observations.

The horizon was stated by Shumard to be the Keokuk, in conformity with the opinion of the earlier geologists; but it is now known to be the New Providence shale (Knobstone), a much earlier formation at the base of the Lower Carboniferous, more or less equivalent to the Lower Burlington, Chateau of Missouri, Waverly of Ohio, and the Mountain limestone of Britain and Belgium (see Springer, Crin. Faun. Knobstone, Proc. U. S. Nat. Mus., vol. 41, 1911, pp. 175-208).

No figure of the type species was given by Shumard; but the form was so peculiar, and unlike any other then known, that there was never any difficulty in recognizing it from the description. The first published illustration of a specimen belonging to this genus was given by Meek and Worthen in 1868, under their species *C. wachsmuthi,* from the Upper Burlington limestone (Geol. Surv. Ill., III, pl. 18, fig. 5). This was followed in 1873 by their species *C. bradleyi,* from the Crawfordsville beds of the Keokuk (*Op. cit.,* V, pl. 14, figs. 10 *a, b*). *C. wachsmuthi* was further illustrated by Wachsmuth and Springer in 1886 (Rev. pt. III, pl. 5, figs. 15, 16). The range of the genus was extended into the Chester (Kaskaskia) through a species described by Wachsmuth in 1882 under the name *Allagecrinus carpenteri* (Bull. 1, Ill. St. Mus., p. 40; Geol. Surv. Ill., VII, pl. 29, fig. 14). The reference to *Allagecrinus* was made under a misunderstanding of the characters of a solitary specimen found by Professor Worthen in Monroe County, Illinois. In the course of collections made for me in recent years at the same locality, I obtained several specimens of this small crinoid in such preservation as to establish beyond question its identity with *Catillocrinus,* and also to show that it is the same form which had been previously found in equivalent strata at Huntsville, Alabama. In the meantime another small species appeared among my collections from Indian Creek, Montgomery county, Indiana, in a horizon of the Keokuk slightly lower than that of *C. bradleyi,* which has remained undescribed until now.

Thus we have in the American rocks a geological range for this greatly specialized genus extending from the earliest to the latest Lower Carboniferous, and occurring in most of its major subdivisions; while the genus itself is the most vigorous representative of a type which as now known ranges from the Devonian (or even Silurian in its direct ancestral form) through the Lower Carboniferous perhaps to the Permian. The relations and evolutionary stages of this type have been extensively discussed by Bather (1893, Crin. Gotl., p. 25; Lankester Zool., pt. III, 1900, p. 150), and by Jaekel (1895, Crin. Deutschl., p. 44).

According to these authors, the line starts with *Pisocrinus* in the Silurian, and, deriving through *Calycanthocrinus* in the Lower Devonian, evolves to *Mycocrinus* in the Middle Devonian of Germany, in which the structural plan afterwards so strongly developed in *Catillocrinus* of the American rocks was definitely established.

Catillocrinus had been referred by Zittel (1879, Handb. Pal., I, p. 348) and by De Loriol (1882, Pal. Franc., XI, p. 46) to the Pisocrinidae; and the relations of the genus with *Calceocrinus* (representing the present family Cremacrinidae) were pointed out by Wachsmuth and Springer in 1886 (Rev. III, p. 267). Discussion of these relations, or of the ancestral line, is not within the scope of this paper, which is intended merely to furnish new and authentic information upon the occurrence and structure of the type included in the family Catillocrinidae as originally defined by Wachsmuth and Springer.

A very notable addition to our knowledge of this type has been made by Professor Wanner in his epoch-making treatise on the Permian Echinoderms of Timor, Part I, published at Stuttgart under date of 1916, but not received in this country until 1921, so that many new genera proposed by him were unknown to American paleontologists until nearly five years after the date of their publication. In this work he has described under the name *Paracatillocrinus* a form which in some of the essentials combines the characters of the Devonian and Carboniferous forms. Thus this type, after a gap represented on this continent by the entire Pennsylvanian series (Coal Measures and Upper Carboniferous) reappears in that far-off region as part of a rich and varied fauna, in which post Devonian representatives from the Lower Carboniferous to the Permian are intermingled, and Mesozoic types anticipated, in a most amazing way.

Acquisition of new material during the years subsequent to the description by the earlier authors enables me more thoroughly to illustrate the species heretofore described, to supply some structural details previously unknown, and to add several new species. To this end it is advisable to assemble the pertinent facts relative to the known genera and species, in the order of their geological succession, beginning with the Devonian:

MYCOCRINUS Schultze

Mon. Echin. Eifl. Kalk., 1866, p. 222 (sep. p. 110)

In this genus, as represented by its type species, *M. boletus,* from the Middle Devonian of the Eifel, the essential structure was established which characterized the subsequent line, namely, a cup composed chiefly of unequal and unsymmetrical radials in contact, two of them much larger than the other three, separated at one end by two of the smaller ones abreast, and at the other end by the third smaller plate, which is somewhat larger than the other two. These radials are greatly thickened at the truncated upper face, which is traversed by curved and radiating food grooves leading to the inner cavity, and connecting at the outer edge with numerous small, thread-like arms, which are borne directly upon the radials, usually one from each of the smaller plates and several from each of the larger, up to a maximum of twenty-five or thirty. This is the generalized picture of the type; the further details apply to *Mycocrinus* especially.

Below the ring of massive radials is an equally massive basal ring, usually protruding as a subglobose knob about half the height and width of the cup, but in one case conical, expanding gradually to the radials. This encloses no cavity, but is solid for its entire height, except as pierced by the nerve canals. It is described as being composed of two unequal plates (Schultze, Echin. Eifl. Kalk. p. 222, (Sep. 110), and as undivided (Jaekel, Crin. Deutschl., p. 55). Of my specimens of the type species, one has the base undivided, and two have two distinct sutures; in one of the latter by a strong light a third line of division may be seen in the proper position. I have little doubt that the primary division was into three plates, of which the sutures were unequally obscured by compression or fusion in life, or by chemical changes during fossilization. A division into two unequal plates by sutures standing at an angle to each other, as in Schultze's figure 4*a,* is mechanically improbable, even in such an anomalous structure as this; there must have been originally a third.

Of the radial ring, the three smaller RR have partly straight sides, and a large curved indentation at the upper corners next to the large RR, which have corresponding projections to fit the space. By means of these lateral extensions the large radials, which at the basi-radial suture are but little wider than the smaller ones, are at the upper face at least twice as wide; but as between themselves there is little difference in size. The usual number of food grooves, one for each arm base, upon the large radials is about six, but may be four or seven, thus making the total number of arms from eleven to seventeen. The arms themselves have not been seen in this genus. The cup is usually more or less elliptic, and all known specimens are small, the maximum not exceeding 11 mm. long diameter.

Of the pair of small radials abreast, one has usually at its distal face to the left a small tooth like elevation, which from analogy of the structure in *Catillocrinus* we know to be connected with the anal plate and tube. This determines the orientation of the calyx, the radial last mentioned being the right posterior, its fellow small one the right anterior, and the third small one at the opposite side of the cup the left anterior; while the two large radials are the anterior and left posterior respectively. This orientation was not observed in some of the earlier descriptions and discussions (*e. g.,* Wachsmuth and Springer called the two large plates "antero-lateral"), which fact must be remembered when comparing them with later statements.

At the perimeter of the upper face of the radials, one opposite to each food groove, are certain slit-like openings, which perforate the plates and pass downward to the basal ring. Their continuation may be seen at the margin of the five-sided pyramidal upper face of the basal knob, of which I have a detached specimen (pl. 1, fig. 9). Considering the great asymmetry which prevails in the parts above, it is remarkable to find in this face a perfect pentagonal symmetry, the openings apparently entering it in regular clusters of three. Schultze describes them as twelve in number, three each in two of the sides and two each in three; but my specimen indicates that there is probably one for each arm.

These openings are for the lodgment of the dorsal nerve cords, which lie back of, or below, the other nerves connected with the food grooves, and proceed from the aboral motor nerve system. Usually they lie in the brachial groove itself, but sometimes, as in this case, they are lodged in a separate axial canal, which perforates the radial facet into the substance of the plates, where it divides and branches to the basals, passing ultimately into the chambered organ. Such perforation of the radials is common in the recent crinoids, and occurs in several Devonian genera, but is not often seen in other paleozoic crinoids. In *Mycocrinus* the canals apparently pass downward directly through the radials and concentrate in the basal knob. But in *Catillocrinus,* which has no such knob, they follow just underneath the food groove for some distance, separated from it by a thin partition (pl. 2, figs. 10, 11, 12), and then turn downward, passing into the usual branches and commissures too minute to be traced in the fossils.

In addition to Schultze's type, another species, *M. granulatus,* has been described by Jaekel, on account of its granular surface; and a third, *M. conicus,* is herein proposed because of its conical, instead of knob like, base. In both of these the base appears undivided, except for one faint suture in the latter.

CHANGES TOWARD CATILLOCRINUS

The change in calyx structure which took place from *Mycocrinus* to *Catillocrinus* consisted chiefly in the reduction of the high, massive, protruding basal knob to a relatively low, and in the typical species exceedingly thin, disk; and in the shape and proportions of the radial plates by which, except in one species, the two larger ones became relatively much wider above, at the expense of the three smaller ones, in two of which the upper face was reduced to a narrow apex. These plates also became bounded by curved lines, except some of those bounding the smaller pair which remained straight. In the last survivor of the degenerative series, *C. carpenteri* of the Chester, there is a tendency to return to the earlier plan; the three smaller radials fill nearly half the circumference of the cup, and their lines are mostly straight.

The thinness of the base, in contrast with its massiveness in *Mycocrinus,* is most remarkable, and almost without a precedent among the crinoids. In the type species, *C. tennesseeae,* it is as thin as fine writing paper, and translucent, so that in some specimens the outline of the infrabasal ring, to be presently described, can be seen by transmitted light.

In this genus we first become acquainted with the actual structure of the slender arms, and of the relatively enormous anal tube, neither of which, however, were known to the earliest describers, nor in their full details until now.

CATILLOCRINUS (Troost) Shumard

Shumard, Catal. Pal. Foss, 1866, p. 357

Shumard's generic diagnosis is as follows:

Catillocrinus Troost, 1850

List, Crin. Tenn. Proc. Am. Assn. Camb. Meeting, p. 60

Generic character. Basal pieces 5, small, forming together a low cone. Primary radials 5? Secondary radials 5, very irregular in form, two of them large, transverse, somewhat lozenge-shaped; two subquadrangular, one lanceolate; their superior edges broad, and marked with strong, radiating, curved sulci. Arms slender, numerous (facets for 56 in the specimen before me), arising directly from the upper straight edges of the secondary radials. Column large, round, the superior joint concealing the basals and nearly the whole of the primary radials.

A fuller description is given under the type species, as follows, p. 358, foot-note:

Catillocrinus tennesseeae. Cup hemispherical, width one and a half times greater than the height. *Base* (concealed by the column) small, pentagonal, situated in a deep cavity, and projecting into the interior in the form of a low cone. *Primary radials* forming united an irregular pentagon, with curved margins which scarcely rise above the plane of the under surface of the cup, almost entirely concealed by the last joint of the column. *Secondary radials* very irregular in form, thick, convex; two very large, transverse, forming almost two-thirds of the cup; expanding rapidly from below upward so as to embrace nearly the whole of the superior circumference; between these on one side are wedged in two of the smaller pieces, one of them quadrangular with nearly parallel sides, the other linguaeform, and opposite these is a large quadrangular piece with sides converging from below upwards.

Adapted to present terminology, the foregoing descriptions undoubtedly call for a dicyclic base. Three ranges of calyx plates are described, one of them being the irregular radials which cannot be mistaken for anything else, and two others below these. It is clear that what the author called " primary radials " are our basals, and what he called " basal pieces " are our infrabasals; the latter form a " low cone, projecting into the interior," and the former an " irregular pentagon with margins which scarcely rise above the plane of the under surface of the cup "; and both of them are covered by the last joint of the column, which conceals " the basals and nearly the whole of the primary radials." In the generic diagnosis the number of small " basal pieces," forming the " low cone," is stated as " 5," while in the specific description the number is not given. Shumard evidently had a very definite idea of the structure before him, and there is no ambiguity in his description. Wachsmuth and Springer, upon the evidence of other specimens accessible to them, but without having seen Shumard's, disputed his interpretation of the structure and maintained that there are " only two series of plates."

The descriptions in Troost's previously unpublished monograph were copied by Miss Wood in Bulletin 64, pp. 23, 24, where they may be consulted in full. They are not material to the present inquiry, except for the statement in the generic diagnosis: " Pelvis (base) subpentagonal, divided into 3 unequal plates "; and in the specific description: " Pelvis (base) irregular pentagon, more or less concave, bearing a circular impression for the column which occupies almost the whole of the pelvis." He recognized only two series of calyx plates, and not three as Shumard did; hence the "pelvis" of Troost is the same element that is called "primary radials" by Shumard.

Thus, while the generic diagnosis shows a divided base of three plates, the specific description, like Shumard's, says nothing about their number. Miss Wood (*Op. cit.*, p. 24), alluding to this, and to the statement by Wachsmuth and Springer (Revision III, p. 368), that the base is undivided, says: "Troost's observation appears to be correct, as the suture lines between the plates show distinctly on one of his specimens, and traces of them appear upon others."

I have the Troost types before me; the original of Miss Wood's figure 3 of plate 9 shows one very distinct suture under r. post. R, and two others, faint but distinguishable in a proper light, under l. post. and r. ant. RR. In the manuscript of Troost's monograph there is a diagram of the cup (not reproduced in the publication) showing two distinct interbasal sutures, and a third one indicated by a dotted line. The three sutures do not meet at the axial center, but connect with a small obtusely pentagonal area in which the thin plates are broken out.

Thus the actual construction of the basal ring has been a matter of doubt among different observers, Troost believing it to be composed of three plates, and Wachsmuth and Springer, and others following them, considering it as undivided; while Shumard puts the number as doubtfully five, with another series below or within them. It is important to ascertain, if possible, what the fact is.

COMPOSITION OF THE BASE

In addition to the Troost types in the original Troost collection in the National Museum, I have a number of good specimens of the type species from the two localities at which it has been chiefly found, Button Mould Knob, Kentucky, and White's Creek Springs, Tennessee; most of them consisting of the dorsal cup only. Careful examination under the best light conditions, including cutting and polishing of some specimens, fails to disclose distinct, unmodified interbasal sutures; but in all the lines of division between the plates are more or less obscured, either by compression, by secondary growth of stereom, or by molecular changes during the process of fossilization. The calcite of which the specimens are composed when not silicified is usually crystallized, developing its characteristic lines of cleavage which tend to obliterate fine sutures—even the basiradial sutures, which we know to be invariably present, being in some cases by no means distinct.

Furthermore, there is undoubtedly in this family a strong tendency to fusion of basals, which causes considerable uncertainty in the composition of the base as we find it in the fossil state. This is nothing unusual. In the extensive family Platycrinidae, which we know beyond question has primarily a tripartite base, there are many species in which the plates are completely fused into an undivided disk. Wanner finds both the divided and undivided base among the Timor species of *Platycrinus,* and of his new genera *Eutelecrinus* and *Neoplatycrinus.* In the Devonian *Triacrinus,* in which the three basals was the sole generic character specified to separate it from *Pisocrinus,* my specimens from the Eifel show 3, 4, and 5 BB. An excellent example showing how this character appears in practice is furnished by a species of *Synbathocrinus, S. robustus,* occurring in the same beds and localities, and under identical conditions of preservation, with *Catillocrinus tennesseeae;* out of 55 specimens, 16 show distinctly all three sutures of the divided base, six show one or two faintly, while in the remaining 33 the base appears undivided.

In the Burlington species of *Catillocrinus, C. wachsmuthi,* in which the basal ring externally appears much the same as in *C. tennesseeae,* though usually somewhat less concealed by the column, there is ample evidence of a divided base, although all the sutures are not usually seen. In three specimens there is a complete division into 3 BB, the sutures meeting at the axial lumen, and leaving no possible space (at the exterior) for infrabasals (pl. 3, figs. 7, 10). So also in the later species of the Keokuk and Chester groups, in which the basal ring is relatively higher and laterally more visible, three well-defined sutures are seen in several specimens, while in others of the same species none can be detected.

Therefore I think it may fairly be concluded from the evidence that the basal ring in some species of this genus is divided into at least three plates, but that owing to the tendency to fusion a partial or complete anchylosis may at any time occur, leaving the observer in doubt as to the actual number of plates. This fact must be strongly emphasized, because the negative evidence as to the presence of sutures in these forms is liable to be extremely misleading, as I have learned from some practical tests. In two fragmentary specimens of *C. tennesseeae,* I carefully prepared the inner surface of parts of the calyx opposite to some of the most prominent sutures, such as those between the radials, always very conspicuous at the exterior. They show that even these interradial sutures, of the presence and exact position of which we are always perfectly sure, are so compressed, or modified by the tendency to fusion, as to be very indistinct at the interior, and sometimes completely invisible. This happens in one case where the plates along the line of an adjacent suture have actually separated. The compression would be even greater in the base, where the surface is overgrown by the large column. Therefore the fact that sutures cannot be seen in a number of specimens in the position where they should be, must not be taken as conclusive of the absence of a primary division among the plates; and a single specimen in which the sutures can be seen is of more weight as evidence than several in which they cannot.

There remain, however, still to be considered the statements in the original descriptions by Shumard, both generic and specific, indicating the presence of three rings of plates in the dorsal cup of *Catillocrinus tennesseeae,* which have hitherto been disregarded. At that time there were no controversies about the " Dicyclic " or " Monocyclic " base, which might influence opinion one way or the other. Shumard was a careful observer, and it has seemed to me improbable that he should have described a structure like this with such particularity without having some persuasive evidence in support of his interpretation. To say that the base was " small, concealed by the column, situated in a deep cavity and projecting into the interior in form of a low cone," was too definite a statement to be founded on mere supposition. Therefore when I acquired the Hambach collection at St. Louis, I looked with special interest among the Shumard types which it contained for the originals of his *Catillocrinus* description; and to my great satisfaction found his two specimens from Button Mould Knob, Kentucky, one of which agrees with his statement above quoted in every particular. Other material contained in collections made for me at the type locality and at White's Creek, Tennessee, and those of S. S. and Victor W. Lyon, also acquired, have furnished considerable confirmatory evidence; so that I am now enabled to present the facts with a wealth of detail unusual in so rare a form.

In the Shumard type specimen the low cone lies at the bottom of the visceral cavity on the inner floor of the calyx, invisible from the dorsal side—not because concealed by the column, as Shumard stated, for the proximal columnal is not attached, but because obscured by fusion, as elsewhere explained. It consists of three nearly equal plates, separated by perfectly distinct sutures which can readily be seen with the naked eye. These plates and their divisions are so distinct that I am forced to believe that where the published generic diagnosis says "basal pieces 5, forming together a low cone," it was due to a typographical error, and should have read "3." At the interior surrounding the cone there is considerable indication of a division of the basal ring into five plates, which was the occasion of Shumard's doubtful statement of "primary radials (basals in our terminology as already explained), 5?"; but the suture lines are not sufficiently distinct to furnish a definite sketch of their position. The floor of the calyx at the median portion of the base is too thin to permit any manipulation of the plates at the exterior, where no trace of the boundary of the cone, nor of any interbasal sutures, can be seen.

The presence of the tripartite cone is fully confirmed by two other specimens, in one of which the cup has been fractured vertically in such a way that the median part of the base is left intact and free from matrix on both surfaces. This contains the cone in all respects similar to that of the Shumard type, with its three plates completely separated by sutures. Not only so, but the line of fracture of the thin base follows about half the perimeter of the infrabasal circlet, which is thus separated from the surrounding basals and left projecting so that its outline is perfectly defined, leaving no doubt that it passed through to the dorsal surface. I have been able to photograph this specimen from both aspects, and also the interior of the Shumard type, so that the structures are accurately shown without any retouching as to these details (pl. 2, figs. 2, 7, 8). In the third specimen (fig. 10*a*) the cone also appears very much as in the Shumard type, but owing to some distortion of the calyx does not yield so clear a photograph.

Two other specimens in which the interior is free from the matrix show the raised contour of the cone, but not the divided plates, the sutures being completely fused. Viewed by transmitted light through the thin base, the obtuse outline of the infrabasal circlet, similar to that which is exposed in the fractured specimen, can be fairly well seen. In all these interior views there are lines more or less obscured by fusion which in my opinion indicate a division of the plates surrounding the cone into five. Upon two other specimens filled with hard matrix, I ground and polished the base at the dorsal side, and found the sutures partially indicated in both, together with the rounded outline of the infrabasal circlet. In one of these I was able to locate four of the interbasal sutures, leaving the position of the fifth obvious. By means of these two specimens, supplementing those previously described, I have inferred the composition of the base, as seen from the dorsal side, consistent with the structure at the inner floor, substantially as I have drawn it in figure 9 of plate 2. The outline of the infrabasal ring is not sharply defined by lines and angles, but is obtusely angular or rounded, as the basal ring itself appears in the same specimens. Its appearance is not unlike that of the base in dicyclic genera like *Eupachycrinus,* where the small infrabasal cone is seen from the interior projecting at the end of a deep funnel.

In two other specimens an obtusely angular or rounded space at the middle of the base is pushed inward from the dorsal side; it is of the same size as the inner cone in other specimens, and looks as if it had been separated from the surrounding basals by external pressure, the central area in one remaining intact but depressed to a lower level than the adjacent surface (pl. 1, fig. 17). In four others a similar space at the center of the base is broken out, but not well defined (pl. 2, figs. 5, 6). It is evident that the infrabasal area was a weak spot in this thin base, since that portion alone is broken away in at least six specimens otherwise intact.

Putting these facts together, we have as evidence bearing upon the composition of the base in this species: Three specimens with the plainly divided cone in place at the inner floor of the calyx, in one of which the exterior boundary is clearly defined by fracture; two in which the space corresponding to it is displaced by external pressure; four in which it is broken out; two polished specimens in which the outline corresponding to the cone is seen from the dorsal side, and at least four sutures connecting with it; and the appearance at the interior of more than three basals surrounding the cone. I find myself unable to explain this assemblage of facts except as proof that in this species there is a dicyclic base, which, however much it may be modified by fusion, consisted primarily of three infrabasals and five basals, as originally described by Shumard.

Whether such a set of plates at the interior exists in any of the later species cannot be ascertained from the material available, but I am certain that infrabasals do not appear at the exterior in any of them; and in view of the definite proof of a division of the basal ring into three plates, as in *C. wachsmuthi* and *C. carpenteri,* in which the sutures are distinctly seen continuing to the axial center, I am of the opinion that in those species the base consists of only the one ring of plates.

If that be true, it means that in the course of successive modifications of this type as represented in the American Carboniferous, perhaps coincident with the decrease in size, the infrabasal ring was eliminated. Such a modification as this would be no more remarkable than the change from the massive, protruding base of *Mycocrinus* to the flat and thin basal disk of *Catillocrinus*. And we have striking examples, as shown in my work on the Crinoidea Flexibilia, pp. 119, 269, 277, etc., of the disappearance of infrabasals in individuals and in species, in *Ichthyocrinus* and other Flexibilia, due to atrophy in forms where, as in this case, almost the entire base is buried underneath the column.

In the Permian member of the family, *Paracatillocrinus,* as described by Professor Wanner, the basal ring appears usually to consist of two unequal plates (in one specimen only a single suture is seen), as is the case in some, but not all, specimens of the Devonian *Mycocrinus*. I very much doubt if that was the primary arrangement in any of them, but believe that the apparently unequal division into two plates is rather due to unequal fusion, as is shown by the fact that in some specimens of *Mycocrinus* the base is completely fused, in some divided unequally by two sutures, and in one by two distinct sutures with a third one present but obscure.

I have given the facts as I find them after a careful study of the excellent material now assembled, corroborated by the observation of a colleague of much experience in this kind of investigation. They present a condition different from what I formerly supposed, and which can only be interpreted as one in which, in a greatly specialized type, along with other departures from the usual habitus of the crinoids, there arose such a degree of instability of the base as to allow it to become dicyclic or monocyclic within the same genus; to be composed of 2, 3 or more plates; or to be entirely undivided. Wanner's studies on the Timor form (Perm. Echinod. Timor, p. 8) led him to the conclusion that the number of basals is not constant within his genus, or even within a species under it, and is therefore a character of only secondary importance.

The extreme flatness of the base, and thinness of its component plates, as exhibited in *Catillocrinus tennesseeae,* does not continue in the succeeding species, after *C. turbinatus*. In *C. wachsmuthi* the basal ring becomes somewhat, though still unsymmetrically, exposed in a side view all around, and correspondingly thickened, as is shown by a fractured specimen (pl. 3, figs. 9, 10) ; and in *C. bradleyi* and *C. carpenteri* it increases farther until it occupies one-fourth to one-third the total height of the cup. But in the Timor species, instead of a further development in this direction, we find a reversion, not toward the structure of the Devonian form, as in the rectangular shape of the smaller radials, but to the flat and extremely low base of *C. tennesseeae*.

ASYMMETRY OF RADIALS

The extreme disproportion in size of the radials in the type species of this genus is accompanied by a further asymmetry, unusual in the crinoids, due to the fact that the basal ring, most of which is covered by the column, projects more or less beyond the column at the anterior side, while at the opposite side it is either invisible or reduced to a narrow band. Also the radials toward the anterior side are somewhat higher than those opposite to them, so that the dorsal cup stands slightly oblique to the vertical axis of the column. This obliquity is more pronounced (but in the reverse direction) in the Timor form. In some of the later crinoids it becomes a very marked feature in their structure, *e. g., Cyrtocrinus mutans* and others figured by Jaekel in 1907 (Körperform der Holopocriniten, p. 279, *et. seq.*). When carried to an extreme, this would result in the complete bending of the calyx to a pendent position, as in the Cremacrinidae. Exceptionally the projection of the basal ring is at the posterior side (2 out of a dozen specimens in *C. tennesseeae,* but none in 8 specimens of *C. wachsmuthi*), which Wanner finds to be the rule in the Timor form, or as he states it the projection is least under l. ant. R. In the later American species, with the increase in height of the basal ring the difference in its projection becomes less.

In connection with the asymmetric proportions of the radials, it results that in the Catillocrinidae the cup is usually elliptic in outline, instead of circular as in most other crinoids. The long diameter bisects the two larger radials. This character is conspicuous in *C. tennesseeae,* the difference between the short and long diameter in an average of 14 specimens being about as 1 to 1.12; it prevails more or less throughout all the species, but least of all in *C. carpenteri* and in *Mycocrinus conicus.* In comparative measurements of the cup in different specimens, if only one figure is stated it means the long diameter.

The asymmetry of the cup in *Catillocrinus* goes so far that even the two larger radials are not equal. With but few exceptions, the anterior radial is wider at the upper margin than the opposite left posterior, and has a greater number of food grooves. The difference varies in the different species, the proportion in width of l. post R. to ant. R. being on an average from 1 to 1.24 minimum to 1 to 1.50 maximum in *C. tennesseeae, turbinatus, wachsmuthi,* and *shumardi;* while in

C. bradleyi it drops to 1 to 1.20, and in *C. carpenteri* still farther to 1 to 1.17—although in the latter case the reduction is due to an increase in r. ant. R. at the expense of ant. R.

The openings at the margin for the dorsal canals in *Catillocrinus* are round, instead of linear as in *Mycocrinus boletus;* in the latter they are very similar in form to those upon the radial facets in *Synbathocrinus.*

MODIFICATION IN LATER SPECIES

The three species next following *C. tennesseeae,* up to that of the earlier Keokuk, agree with it in the essential structure of the calyx other than that of the base—the arrangement and relative proportions of the radials being about the same within the limits above mentioned. In the progress of the type from there on some remarkable changes took place. The first of these relates to the mechanism of the anal side controlling the attachment of the tube to the cup, and it includes both *C. bradleyi* of the later Keokuk and *C. carpenteri* of the Chester. It is marked externally by the disappearance in the last two species of the raised process on the right posterior radial which is present in the first four, so that the distal face of that radial is at the same level as that of the others. This is accompanied by a singular modification of the anatomy at the base of the tube, which will be explained farther on.

But while *C. bradleyi* remained substantially in line with the four preceding species in the distribution and size of the radials, *C. carpenteri* proceeded to depart from all its predecessors by taking on a radial arrangement of its own differing from that of all others in the family. This is effected by an increase in the size of r. post. R. and r. ant. R. and reduction in that of the two larger radials until they occupy no greater part of the circumference of the cup than they do in *Mycocrinus.* But in addition to this the r. ant. R. is increased much more than its fellow of the pair, so that now, instead of narrowing to an apex as in other *Catillocrinus,* and bearing only a single arm as it does in all other species within the family, it becomes widest above, and supports almost as many arms as the adjoining ant. R.—having 3 to 5, or an average of 23 per cent of the total number of arms, as against 7 per cent in *Mycocrinus* and 2 per cent in *C. tennesseeae.* Such a departure from one of the prime characteristics of the family, correlated with the diminution in size, shows a loss of vigor in the type presaging its extinction.

THE ANAL TUBE

Considering the small size of the calyx otherwise, and the extreme delicacy of the arms, the anal tube of *Catillocrinus* is an extraordinary structure. It is of a type occurring also in *Pisocrinus, Deltacrinus* and probably other Cremacrinidae, and also, though rarely seen, in *Synbathocrinus,* but here carried to the extreme, viz., a long, heavy, semicylindrical appendage, reaching to (and probably beyond) the ends of the arms, and thicker at the base than half the diameter of the cup. It is composed of a single series of extremely heavy plates, longitudinally arranged, thickest at the back (posterior side) from which they are transversely curved like arm-plates, and taper in a crescent to thin edges, leaving a broad, semicircular furrow at the anterior. This furrow was enclosed by a flexible integument of small plates, so fragile that it is not preserved intact in the fossils, although I find some traces of it. Large ligament fossae on the apposed faces of the plates indicate some flexibility in the tube. The massive character of the tube and its component plates is seen in *C. tennesseeae* and *C. wachsmuthi* (pl. 2, figs. 14, 15; pl. 3, fig. 4), and its extreme elongation in *C. bradleyi,* where it reaches a length of fifteen times the height of the dorsal cup (pl. 3, figs. 14, 15), and in *C. carpenteri* twenty and twenty-eight times (pl. 4, figs. 1, 2). There is little diminution in thickness after the first plate.

In the lower part, the tube is marked externally by slight longitudinal grooves, which are the permanent imprint of the arms when closely folded against it. The lowest tube plate expands somewhat towards the cup, and serves in part the purpose of a tegmen; at the back it is almost as thick as the radials upon which it is superimposed, and its under surface is crossed by curving furrows partly, but not in full detail, corresponding to the food grooves upon the upper face of the radials, for which to that extent it forms a solid roof. As this lower tube plate only surmounts the upper face of so much of the radial circlet as lies at the posterior side, the food grooves toward the anterior must be covered by small covering pieces or perisome continuous with those upon the arms.

Now this lower tube plate, exactly at its thickest part, rests upon an elevated process upon the left shoulder of the right posterior radial which is usually rather narrow exteriorly, but widens considerably inward, forming a prominent trapezoidal platform separating the groups of food grooves upon the two large radials. At its outer edge the tube plate is indented with a curved socket for the reception of a triangular anal plate which appears between the arms at the exterior margin of the cup, and also extends deeply inward, where it interlocks with the tube plate by means of the socket. Among fragmentary specimens I have a number of separated tube plates, including several of the lower ones, all of which have the curved socket as above described (pl. 2, fig. 17); and in one of them (fig. 18) the anal plate remains firmly attached by the socket in its original position; in others (figs. 14, 16) the relation of the tube plate with its socket to the raised process at the margin of the cup is shown as it appears in the absence of the anal plate and arms.

This is the structure of the parts at the posterior side in *C. tennesseeae;* and in *C. wachsmuthi* I am able, after some careful preparation, to show the tube itself in position, with its interlocking key-plate wedged into the socket precisely as it was in life—an admirable device for anchoring such a ponderous appendage (pl. 3, figs. 4, 5). The two other closely associated species, *C. turbinatus* and *C. shumardi,* have the same elevated process for supporting the anal plate, and their structure in relation to the tube is undoubtedly the same—thus including in this class all species up to the earlier Keokuk.

But in the two succeeding species with which the series terminated, *C. bradleyi* of the later Keokuk and *C. carpenteri* of the Chester, a curious change occurs—a striking example of the infinite variety which characterizes the processes of nature. The raised platform disappears, and with it the anal plate; instead of them a rather wide plate rests directly upon the upper face of the radial, at the same level as that of the other radials, filling its entire width except space enough at the right side for one arm, and bending inward between the arms. This is entirely different from the separate anal plate above described, but is itself the first plate of the tube. The connection is beautifully shown in the two specimens of *C. bradleyi* (pl. 3, figs. 14, 15), in which the long tube is exposed from its origin on both right and left sides. It is also well shown in a specimen of *C. carpenteri,* on which I removed the arms sufficiently to expose the tube in a side view (pl. 4, fig. 18). Other specimens of both species, figured on the same plates show the form and proportions of the first tube plate seen directly from the posterior.

The course of the four antecedent species, having the anal structure first above described, was marked by a steady decrease in size. *C. bradleyi,* in which the change was introduced, took on renewed vigor, with increase in size and relative number of arms. But the change was not permanently advantageous, and the next species, *C. carpenteri,* after undergoing still another modification in the arrangement of radials and arms, already mentioned, passed into an impoverished condition with which the line was extinguished.

Such a change in the anal structure as above described would in other groups be considered as ground for generic separation, but in a type so highly specialized as this, on the eve of its extinction, these characters are so completely overbalanced by those which have become dominant, that they may well be regarded as of secondary importance. The raised process is present in the Devonian genus, but apparently not in the Timor form; this would indicate that the tube structure in *Mycocrinus* was according to the plan of *C. tennesseeae* and its allies, while that of *Paracatillocrinus* was like that of *C. bradleyi* and *C. carpenteri.*

If it should be thought that my view of the significance of this character is too conservative, then the later section might be ranked as a new genus under the name *Eucatillocrinus,* with *E. bradleyi* as genotype. But in order to be consistent this should be followed up by setting off *C. carpenteri* as another genus on account of its difference in radials and arms.

With the enormous space enclosed by the tube in proportion to the small size of the cup, it must have had some other function than that of a mere excretory organ. It may have lodged the genital apparatus.

RELATIONS WITH OTHER GENERA

As already remarked, the tube is of the same type that occurs in *Pisocrinus, Deltacrinus* and *Synbathocrinus,* and doubtless throughout the families to which they belong. As it is rarely seen in these genera, I am giving figures of some specimens in which it is exposed (pl. 5, figs. 1, 3, 9, 20, 21). They show a certain relationship among these forms, notwithstanding their remarkable differences and specializations in other characters. Indeed the similarity is somewhat striking between *Synbathocrinus* and *Catillocrinus,* the one a model of symmetric adjustment of all its parts, and the other an example of the extreme to which a disturbance of the most stable element in crinoid morphology can go.

Aside from the asymmetry of the radials, the differences between the two genera are chiefly matters of degree. The general form of cup, plan of construction of tube and arms, and the mutual relation of these parts, are substantially the same in both, only the relative proportions are reversed. With the five strong arms in *Synbathocrinus* the tube which they enclose is dwarfed, while in *Catillocrinus* it is the ponderous tube that supports the thin and numerous arms. Both have the greatly thickened radial facets, which are accompanied in both by the rather rare feature of perforation by dorsal canals (see various figures on plates 2 and 5). Their respective families both started in the Devonian and culminated in the Lower Carboniferous of America or in the Permian of Timor. If we take *Pisocrinus* as the beginning of this line in the Silurian, then both ran a parallel course with the Cremacrinidae, except that the latter started first in the Ordovician, ended a little earlier in the Keokuk, and have not thus far been reported from Timor.

The description of the anal tube of *Synbathocrinus* given by Wachsmuth and Springer in Revision of the Palaecrinoidea, pt. 3, p. 167, pl. 4, fig. 11, as being composed of five longitudinal rows of plates, will have to be corrected. We have it now preserved in several specimens, and its structure is uniformly as shown in figs. 1 and 4 of plate 5, namely, a single longitudinal series of strong crescentic plates at the posterior, having the curve completed by an integument of small plates, substantially as in *Catillocrinus*.

THE ARMS

The arms are the most delicate in proportion to their length of any known in the fossil crinoids. They are unbranched, very long, extending nearly to the end of the tube, around which they are closely packed and supported when at rest in shallow grooves, abutting all around in a continuous circlet except for a short distance at the posterior side, where they are separated by the anal and tube plates above mentioned. They differ in size in the different species, those of *C. tennesseeae* being the thickest, about 1.33 mm. in width, while in *C. bradleyi* the arms are less than .50 mm. wide, being thus not only relatively, but actually, the thinnest of all. The fact that several arms, up to as many as 31 on a single plate, are borne directly upon some of the radials, differentiates this form and its congeners from the other crinoids generally, although this structure was foreshadowed in *Calycanthocrinus* of the Lower Devonian.

Considerable importance has been attached to the number of arms, especially by Jaekel, who has taken the increasing number as a controlling character in the progressive developmental series by which he traces the evolution of this type, conformably to the geological succession, from *Pisocrinus* of the Silurian with 5 arms, *Calycanthocrinus* and *Mycocrinus* of the Devonian with 9 to 17 arms, to the successive Lower Carboniferous species of *Catillocrinus* from *C.*

wachsmuthi with 34-38 arms to *C. tennesseeae* with 51-57 arms (Pal. Deutschl. 1895, p. 44). Wanner has pointed out (Perm. Echin. 1, 1916, p. 7) that the succession does not hold good for the Permian forms, in which the number of arms is reduced to 13-20. Jaekel's theory also falls when tested by the facts relating to the species of *Catillocrinus*. For *C. tennesseeae,* the species with the greatest number of arms, instead of being the last in the geological series, as then supposed and so listed in the works of that time, is the earliest; and the modification in number of arms in geological succession proceeds in exactly the reverse of what he assumed—diminishing from 35-58 in *C. tennesseeae* of the earliest Lower Carboniferous, to 13-20 in *C. carpenteri* of the latest member. Thus the end of the series in the American rocks is marked by a retrogression, finishing in the Chester (Kaskaskia) with a degenerate species, the smallest of all, ranging from 2.5 to 4.5 mm. diameter, and represented by a number of specimens from three distinct localities.

With our present knowledge of the different occurrences of this type, it seems evident that the number of arms is largely a matter of size, both as between the different species, and among individuals within the same species. And the two characters taken together form an excellent means of differentiating the species in the successive geological formations. In *C. bradleyi,* however, the arms are more slender than in any other species, and their number, in proportion to size of calyx, is greatly increased.

Catillocrinus tennesseeae, the earliest, is also the largest known species, ranging in our collections from 18 to 27 mm. (exceptionally 13) longer diameter of the elliptic dorsal cup, measured at the upper edge; and the number of arms increases correspondingly from 43 (exceptionally 36) to 58. The closely allied *C. turbinatus,* from the same formation, has a calyx of 11 to 21 mm., with 37 to 53 arms. In the next succeeding species, *C. wachsmuthi* of the Upper Burlington limestone, the size diminished to 6-12 mm., and the corresponding number of arms to 24-39. It was followed by the new species, *C. shumardi* in the Keokuk, a still smaller species with diameter of 4-6 mm., and arms 20-25. Next came *C. bradleyi* from a higher horizon of the Keokuk, a species of more vigorous growth but smaller arms, ranging from 6.5-8 mm. diameter with 40-46 arms. Finally, in the latest member of the Lower Carboniferous, the Chester (Kaskaskia), we have the end of a retrogressive series, in which the size is reduced to 2.5-4.5 mm. diameter, and the accompanying number of arms to 13-24. There is a sufficient number of specimens to prove

COMPARATIVE TABLE OF SPECIES

			Diameter	Height	L. ant.	L. post.	R. post.	R. ant.	Ant.	Arms.
Permian.		Paraca-tillocrinus.	12 ×13.5 9.8×12.7	4.9 4.5	1 1	9 5	1 1	1 1	11 6	23 14
Lower Carboniferous	Chester.	Catillocrinus carpenteri.	4 × 4.7 2 × 2.5	3 2	1 1	8 5	1 1	5 3	9 3	24 13
Lower Carboniferous	Keokuk, Upper.	Catillocrinus bradleyi.	5.2× 8 5 × 6.5	6 5	1 1	20 17	1 1	1 1	23 20	46 40
Lower Carboniferous	Keokuk, Lower.	Catillocrinus shumardi.	4.5× 6 2 × 4.5	2.2 2	1 1	10 8	1 1	1 1	12 9	25 20
Lower Carboniferous	Burlington.	Catillocrinus wachsmuthi.	11 ×12.5 5 × 6	5 3	1 1	16 9	1 1	1 1	20 12	39 24
Lower Carboniferous	New Providence Shale (Knobstone).	Catillocrinus turbinatus.	19 ×21 8 ×11	5 4.5	1 1	21 14	1 1	1 1	29 20	53 37
Lower Carboniferous	New Providence Shale (Knobstone).	Catillocrinus tennesseeae.	25 ×27 17 ×18	10 8	1 1	24 18	1 1	1 1	31 22	58 43
Middle Devonian.		Mycocrinus.	9 ×11 5 × 5.5	5 5	1 1	6 4	1 1	1 1	7 4	16 11

that the correlation of these two characters, size and number of arms, within the limits above stated, is constant for the several species, which are at the same time strictly limited in their stratigraphic position.

Stated in tabular form, the relation in this respect of the species, to which for further comparison I add the data for the Devonian and Permian forms, is shown on page 22, maximum and minimum figures of size being given with the corresponding number of arms.

The column has the tapering proximal enlargement of thin plates that is seen in many of the Flexibilia; and the top columnal is almost as large as the entire base, burying the greater part of its plates and thus producing a condition favorable to the atrophy of infrabasals. From the end of the tapering cone distalwards it is long and slender, terminating in a pointed root adapted to quiet conditions in the soft ooze.

Catillocrinus ranged through the long time interval of the Lower Carboniferous without any material change in the shape and relative proportions of its radial plates, except in the latest species on the eve of extinction. It is now a singular fact that when this specialized type, having run its course and become extinct in the seas which produced the sediments of the American continent, appears in another continent unconnected with this, it should be in a form which in regard to its radial structures reverts to the plan of the European Devonian, while in regard to the character of the base it takes on the plan of the American Lower Carboniferous—thus combining two of the leading characters of its widely separated predecessors.

RÉSUMÉ OF CHARACTERS

For convenience of reference, I will add a résumé of the characters showing the relation of the genera and species of this family, with citation of the principal pertinent literature.

Family CATILLOCRINIDAE

Wachsmuth and Springer, Rev. Pal. pt. 3, 1886, p. 267.—Bather, Crin. Gotl., 1893, p. 25; Lankester Zool., 1900, pt. 3, p. 150.—Jaekel, Crin. Deutschl., 1895, p. 44.

Inadunate crinoidea, highly specialized; with unequal radials all in contact, two much larger than the other three, greatly thickened at the distal face, traversed in a dorsoventral direction by food grooves, one for each arm, and perforated by dorsal canals. Numerous slender, unbranched, non-pinnulate arms are borne directly upon the radials, several to each of the larger plates. Cup generally transversely elliptic, low and broad, expanding upwards; dimensions ranging from 3 to 27 mm. long diameter, and from 2 to 10 mm. high; number of arms from 11 to 58.

Distribution. Devonian to latest Lower Carboniferous (? Permian); Europe, America and East Indies.

MYCOCRINUS Schultze

Echinod. Eifl. Kalk., 1865, p. 222.—Wachsmuth and Springer, Rev. Pal. pt. 3, 1866, p. 272.—Jaekel, Crin. Deutschl., 1895, p. 55.

Base high, protruding, at least half the total height of cup, forming a solid mass pierced by nerve canals, but enclosing no cavity; consisting of 2, probably 3, plates, which may be completely fused. The three smaller RR rectilinear, except where indented at the upper corners adjoining the large plates; the two large RR occupying not over 65 per cent of the perimeter at the upper edge of cup; r. post R has elevated process on left shoulder for support of anal plate.

Dimensions: Long diameter 5.4 to 11 mm.; height 3 to 5 mm.; number of arms 11 to 17.

Genotype. M. boletus Schultze. Three species; two heretofore described, and a new one proposed herein.

Distribution. Middle Devonian; Eifel, Germany.

Mycocrinus boletus Schultze

Plate 1, figs. 1-10

Echinod. Eifl. Kalk, 1866, p. 222 (sep. p. 110), pl. 7, fig. 4.—Wachsmuth and Springer, Rev. pt. 3, p. 272.

BB forming a prominent knob, about one-half the height and width of cup; usually divided into two plates, in one specimen into three, and in one undivided. Transverse outline of cup strongly elliptic. Surface smooth. Diam. 7-11 mm.; height 3-5 mm.; arms 15-16.

Material studied, three specimens, besides the Schultze type at the M. C. Z., Harvard. Nollenbach, Prüm, Kerpen, Eifel.

Mycocrinus granulatus Jaekel

Crinoidea Deutschland, 1895, p. 55, pl. IV, figs. 4*a-c*

Like *M. boletus,* but surface granular, and arms 17; base undivided. Diam. 5.4 mm.; height 3 mm. Founded upon a single specimen from Prüm, Eifel.

Mycocrinus conicus n. sp.

Plate I, figs. 11-13

BB more than half the height of cup, and about as wide at the basi-radial suture; not forming a prominent knob, but a cone sloping about evenly with the ring of radials; one interbasal suture visible, opposite r. post. R. Transverse outline of cup about circular. Diam. 5.5 mm.; height 5 mm.; arms 11.

Founded on a specimen in the author's collection from Nollenbach in the Eifel.

CATILLOCRINUS (Troost) Shumard

Catal. Pal. Foss. Trans. Acad. Sci., St. Louis, II, 1866, p. 357.—Meek and Worthen (*Nematocrinus*), Proc. Acad. Nat. Sci. Phil., 1866, p. 251; Geol. Surv. Ill., III, 1868, p. 465; V, 1873, p. 504.—Wachsmuth and Springer, Rev. Pal. pt. 3, 1866, p. 268.—Bather, Crin. Gotl., 1893, p. 25; Lankester Zool., pt. 3, 1900, p. 150.—Zittel-Eastman, Text-book Pal., 1896, p. 153.—Jaekel, Crin. Deutschl., 1895, p. 44.—Wood, Bull. 64, U. S. Nat. Mus., 1909, p. 23.—Wanner, Perm. Echin. Timor, 1916, p. 6.

Cup broadly truncate above and below, with column facet covering almost the entire base. Base not protruding conspicuously but forming a low disk, usually flat, or projecting more or less unequally above the column; composed primarily either of five basal plates, usually anchylosed or compressed, with sutures invisible or obscure, and enclosing a circlet of three small infrabasals; or of a single circlet of three unequal plates, the smaller one in left posterior position. One of the small RR (r. post.) rectilinear; r. ant. R triangular with one side curved; l. ant. R heart-shaped or narrow triangular; each bearing a single arm. The two large RR usually occupying 80 to 90 per cent of perimeter at upper edge of cup, and bearing a like proportion of the arms; l. post. R. to ant. R as 1 to 1.4. Exception as to form and proportions of RR in *C. carpenteri.* Transverse outline of cup usually elliptic. Arms in contact all around, except where separated for a short distance at posterior side by anal or tube plate; their number varying with species and with individual growth. Anal tube large, massive, extending to or beyond the ends of arms. Column round, with proximal enlargement of short columnals, tapering and becoming longer distalwards.

Dimensions: Long diameter of cup 2.5 to 27 mm.; height 2 to 10 mm. Number of arms 13 to 58.

Genotype.—*C. tennesseeae* (Troost) Shumard. Six species; four described heretofore, and two here proposed as new.

Distribution.—Lower Carboniferous, Mississippian, from the earliest to the latest member. Interior continental area of North America.

Catillocrinus tennesseeae (Troost) Shumard

Plate 2, figs. 1-22

Catal. Pal. Foss. Trans. Acad. Sci., St. Louis, II, 1866, p. 358. Wood. Bull. 64, U. S. Nat. Mus., 1909, p. 24, pl. 9, figs. 1, 2, 3.

The largest species. Cup truncated above and below, broadly spreading, low hemispheric with convex sides, about three times as wide as high. Base flat, forming an irregularly pentagonal disk mostly covered by the column, projecting unsymmetrically chiefly at left anterior side; composed of two rings of plates, viz., 3 IBB forming a low cone, distinct at the inner floor, but fused externally beneath the column; and probably 5 BB, of which the sutures are usually obscure or invisible owing to fusion, and only irregularly identifiable. Arms stouter than in other species, being about 1.33 mm. in thickness. RR typical for the genus; r. post. R has elevated process on left shoulder, supporting triangular anal plate at outer margin, which interlocks inward with first tube plate. Surface strongly pustulose. Material studied, 30 specimens.

Diam. in 14 specimens, 18-27 mm.; height 7-10 mm.; arms 43-58. Exceptional specimen smaller.

Mississippian, New Providence shale; Button Mould Knob, Kentucky, and White's Creek Springs, Tennessee.

Catillocrinus turbinatus n. sp.

Plate 1, figs. 14-17

Similar to *C. tennesseeae,* and occurring in the same formation, but probably at a slightly different horizon. It is typically smaller and lacks the rounded contour of that species, the cup being turbinate, with nearly straight sides; and the base more erect at the sides and projecting above the column all around. Surface smooth or finely granular. It is founded on three good specimens, one a nearly complete crown. Two of them are of the minimum size, while the third is much larger, probably a variant from *C. tennesseeae.*

Diam. 11-21 mm.; height 5-7 mm.; arms 37-53.

Horizon and localities the same as those for the last species.

Catillocrinus wachsmuthi (Meek and Worthen)

Plate 3, figs. 1-11

Synbathocrinus (*Nematocrinus*) *wachsmuthi,* Proc. Acad. Nat. Sci., Phil., 1866, p. 251; *Catillocrinus wachsmuthi,* Geol. Surv. Ill, III, 1868, p. 465, pl. 18, fig. 5.—Wachsmuth and Springer, Rev. Pal. pt. 3, pl. 5, figs. 15, 16.

Of medium size, maximum individuals being much smaller than the typical minimum of *C. tennesseeae,* and the average smaller than the smallest of *C. turbinatus.* Cup broadly spreading as in the former, with rather straight sides as in the latter. Base low, projecting slightly and unequally above the column, chiefly at left anterior side; composed of three unequal BB, distinctly divided in three specimens without any indication of IBB, the interbasal sutures extending without interruption to the axial center; r. post. R has raised process supporting narrow elongated anal plate, which interlocks with first tube plate. Surface smooth or finely granular. Eight specimens.

Diam. 5-12 mm.; height 3-5 mm.; arms 24-39.

Mississippian, Upper Burlington limestone; Burlington, Iowa.

Catillocrinus shumardi n. sp.

Plate 3, figs. 12, 13

Similar to last, but uniformly smaller; 3 BB plates distinctly shown, with no evidence of IBB. Has raised process on r. post. R. Based on four good specimens.

Diam. 4-6 mm.; height 2-22 mm.; arms 20-25.

Mississippian, Keokuk limestone, lower horizon than next species; Indian Creek, Montgomery County, Indiana.

Catillocrinus bradleyi, Meek and Worthen

Plate 3, figs. 14-17

Geol. Surv. Ill., V, 1873, p. 504, pl. 14, figs. 10*a*, *b*

Of medium size. Cup higher and more rounded than in *C. wachsmuthi,* highest at anterior side. BB 3, unequal, about one-third the height of cup, sutures usually obscure. No IBB. Arms about .45 mm. in width, being the most slender of all species. Large RR proportionally not so large as in preceding species; r. post. R. has no raised process at outer edge, and no interlocking anal plate, but first tube plate rests directly on radial at same level as arm bases. Anal tube strong and of great length. Surface smooth or finely granular. Column attaining a length of 31-37 cm., with columnals alternating below the proximal enlargement for about one-third its length, and uniform beyond that to near the end, where it tapers to a fine point and bears a few scattering cirri. I have two specimens in which the column is preserved to its full length. Six specimens.

Diam. 6.5-8 mm.; height 5-6 mm.; arms 40-46.

Mississippian, Keokuk limestone, upper horizon; Crawfordsville, Indiana.

Catillocrinus carpenteri (Wachsmuth)

Plate 4, figs. 1-18

Allagecrinus carpenteri, Geol. Surv., Ill, VII, 1882, p. 341, pl. 29, fig. 14.

The smallest species, being the end of a degenerative series; represented by twenty specimens from three different localities, uniformly within the size limits given below. Cup relatively higher and less spreading than in the other species. No IBB. BB about one-third the height of dorsal cup, rising about equally all around; divided into three unequal plates by sutures under r. post., ant., and l. post. RR in several specimens, a single suture distinctly seen in several and none at all in some. Form and proportions of RR different from those of all preceding species; r. ant. R rectilinear and much larger, bearing 3 to 5 arms; l. ant. R narrower, and the two larger RR occupying but little over half the circumference of the cup at upper edge; r. post. R has no raised process, but first tube plate rests directly upon it at the level of the arm bases, without any separate anal plate. Arms very slender, mostly about .55 mm. in width, but in smaller specimens some arms may be stouter than others, especially the single arms on r. post. and l. ant. RR. Anal tube 25 to 30 times the height of dorsal cup.

Diam. 2.5-4.7 mm.; height 2-3 mm.; arms 13-24.

Mississippian. Lower part of Chester (Kaskaskia); Monroe County, Illinois, Owen County, Indiana, and Huntsville, Alabama.

This species, on the eve of extinction of the genus, shows a marked departure from its characters in the relative proportions of the radial plates. The two larger RR are relatively smaller, r. ant. R has lost the curve at the right side, and has become almost as large as ant. R, bearing 3 to 5 arms instead of only one as in other species. Ant. and l. post. RR lack the great increase in width at the upper side, and in consequence the upward expansion of the cup is less. These characters are constant in eight specimens, from the two principal areas, in which I was able to free the cup from the matrix sufficiently for accurate measurements. The species also, in common with *C. bradleyi,* departs from the others in the structure of the anal side.

PARACATILLOCRINUS Wanner

Plate 5, figs. 22, 23, 24

Permischen Echinodermen von Timor, I, 1916, p. 6

General form of calyx similar to that of *Catillocrinus.* Base forming a low disk, composed, so far as known, of two basal plates, or undivided; projecting unequally beyond the column, chiefly at the right posterior side. The three smaller RR rectilinear, and not narrowing upward; the two large RR proportionally wider below and narrower above than in typical *Catillocrinus.* Transverse outline of cup elliptic.

Dimensions: Long diameter 12 to 18 mm.; height 4.9 to 6; number of arms 13 to 23.

Three species. All from a formation considered Permian by the Dutch and German geologists. Island of Timor, Dutch East Indies.

Paracatillocrinus granulatus Wanner

Diam. 13.5 mm.; height 4.9-5.5; arms 22-23.

Paracatillocrinus spinosus Wanner

Diam. 18.8 mm.; height 5.2 mm.; arms 13.

Paracatillocrinus ellipticus, Wanner

Diam. 12.7 mm.; height 6 mm.; arms 14.

All described in Professor Wanner's work above cited, pp. 10-15; pl. XCVI, figs. 1-4.

NEW SPECIES OF COLLATERAL GENERA

As bearing on the geological range of *Synbathocrinus* in comparison with that of the Catillocrinidae, I have figured two new species of that genus, and another of one closely related:

Synbathocrinus hamiltonensis n. sp. Pl. 5, figs. 13, 14

Differs from other species in the great depth to which the notch for the reception of the anal plate is incised, and in the relatively large size of the anal and succeeding plates. It is represented by a single specimen from the Moscow shale of the Hamilton group, Middle Devonian; on Kashong Creek, near Bellona, New York. A small species from the western Hamilton, *S. matutinus,* was described by Hall,[1] which has been recognized in Iowa and Michigan. It has a much lower calyx than this.

Synbathocrinus onondaga n. sp. Pl. 5, figs. 15, 16

This is a small species of which the material is not sufficient for close comparison, but its special interest lies in the fact that it is the earliest known occurrence of the genus, being from the lower member of the Middle Devonian, the Onondaga; below the hydraulic

[1] Geology of Iowa, Vol. 2, p. 483, pl. 1, fig. 2.

beds, at Louisville, Kentucky. Two specimens are figured, and there is a third fragment in the collection; these were found by different collectors who all agreed in referring it to the horizon above stated.

Phimocrinus americanus n. sp. Pl. 5, figs. 17-19

This species is described here because it is the first occurrence in America of the closely related Synbathocrinid genus characterized primarily by having five basals, instead of three. Correlated with this character it presents a difference in the relative thinness of the radial plates, which also seem to lack the conspicuous processes which are prominent in both the Eifel species described by Schultze[1] when proposing the genus. In this respect, as well as in the elongate form of the calyx, and the sharply notched incision for the anal plate, our American species is to be compared with *P. jouberti* Ochlert, of a corresponding geological position, being from the Lower Devonian, at Sablé, France. The transverse lines indicating a primitive division of three of the radials mentioned by M. Oehlert in his description,[2] and by Bather,[3] are not seen in the unique type specimen of the present species, in which, also, the edge of the radials bordering the inner cavity at the ventral side is not very well defined.

The species is founded upon a single specimen from the Linden formation of the Helderbergian, Lower Devonian, in Benton County, Tennessee, where it was associated with *Edriocrinus dispansus, Stereocrinus helderbergensis,* and some other peculiar forms.

STRATIGRAPHIC POSITION OF THE TIMOR CRINOIDS

I have throughout this paper followed Professor Wanner in referring the Timor member of this family to the Permian age. The fossil faunas which have been uncovered in that Island by the Dutch and German geologists are amazingly prolific, and only a portion of them have as yet been described. Immense collections have been made subsequent to those upon which Wanner's first volume on the echinoderms, covering the crinoids only, is based. His treatise on the blastoids, which are said to be even more numerous than the crinoids, is yet to appear; and after that a supplementary part on the crinoids of the later collections. I have no doubt that the greater part of these faunas are properly referred to the Permian. But, speaking only of the echinoderms thus far described, I cannot avoid the impression that there is also a strong intermingling of Lower Car-

[1] Mon. Echin. Eifl. Kalk., p. 29, pl. 3, figs. 6, 7.
[2] Bull. Geol. Soc. de la France, t. X, 1882, p. 353.
[3] Lankester's Treatise on Zoology, pt. 3, 1900, p. 152.

boniferous types. Out of 24 genera of crinoids described by Wanner from Timor which either occur also in Europe or America, or both, or are of types comparable to others which so occur, 11 are restricted to the Lower Carboniferous or earlier, 8 range from the Lower to the Upper Carboniferous, 3 are known from the Upper Carboniferous only, and 2 from the Permian. From what I have been informed in regard to the blastoids, I should expect even a stronger representation of Lower Carboniferous types.[1]

There are, of course, other crinoid types which have no known representatives elsewhere.

The stratigraphy of Timor is extremely complicated. Great dislocations of the sedimentary deposits have taken place, caused by volcanic action and other earth movements, so that many of the richest fossiliferous strata have become isolated, and their continuity often abruptly disturbed. Professor H. A. Brouwer, of Delft, Holland, whose knowledge of the geology of Timor and adjacent islands is most intimate, based upon extensive personal investigations, informs me that during the Tertiary mountain-building process the Paleozoic, Mesozoic and older Tertiary rocks were intensely folded and overthrusted, the less resistant layers between the more resistant ones being sometimes entirely squeezed out, while blocks of hard limestone of very different age are frequently found close to each other. This phenomenon is often repeated in the details of a relatively thin complex of strata, and the result at many places is a mosaic of rocks of different character and age. Thus it is possible that sediments of different horizons have been thrown together, or so distributed that their relation to one another has been obscured.

Ninety-five per cent of the genera and at least 80 per cent of the species of crinoids described by Wanner are recorded from a limited area at and near Basleo and Niki-Niki, which is in the middle part of the Dutch possessions on the island; and in this relatively small region are found all those types characteristic of widely separated horizons elsewhere. No sufficient data are available to determine whether the intermingling of types as found in the fossils is due to the complicated structure resulting from the dynamic movements above mentioned, or whether it actually occurred in life as the result of faunal developments wholly independent of those occurring in other parts of the earth.

[1] Bather when describing two species of *Schizoblastus* from Timor in 1908 (Neues Jahrb. f. Min., Bd. XXV, p. 319) stated that until further facts were forthcoming he must "consider these species as of Lower Carboniferous age."

EXPLANATION OF PLATES

Unless otherwise stated, all figures are natural size, and all the specimens are in the author's collection in the United States National Museum.

Plate 1

PAGE

Mycocrinus boletus Schultze 24

Figs. 1, 2, 3. Right posterior, basal, and ventral views of specimen from Prüm; showing the knob-like basal ring (here completely anchylosed); the relatively large size of the three smaller radials, their indentation at the upper corners adjoining the larger plates; food grooves for 16 arms, and the slightly elongate openings for the corresponding dorsal canals at the arm facets; the raised process on r. post. R. is well shown. × 3.

4, 5, 6. Similar views of a smaller specimen from Kerpen; showing the same features as the last, but with 15 grooves, and basal ring unequally divided by two well-marked sutures. × 3.

7, 8, 9. Similar views of a detached basal ring from Nollenbach, divided by two distinct sutures and a third faint one; it shows the completely solid nature of these plates, enclosing no cavity, but rising on the upper side into a low pyramid, symmetrically pentagonal, pierced by the central axial canal, and three dorsal canals at each of the peripheral sides.

10. Generic diagram based upon the foregoing specimens.

All Middle Devonian, Eifel limestone; Eifel, Germany.

Mycocrinus conicus n. sp 25

11, 12, 13. Right posterior, left anterior, and ventral views of type, from Nollenbach; showing the relatively higher and more conical basal ring, obscurely divided, and food grooves and dorsal canals for 11 arms. × 3.

Same horizon and area as last.

Catillocrinus turbinatus n. sp 26

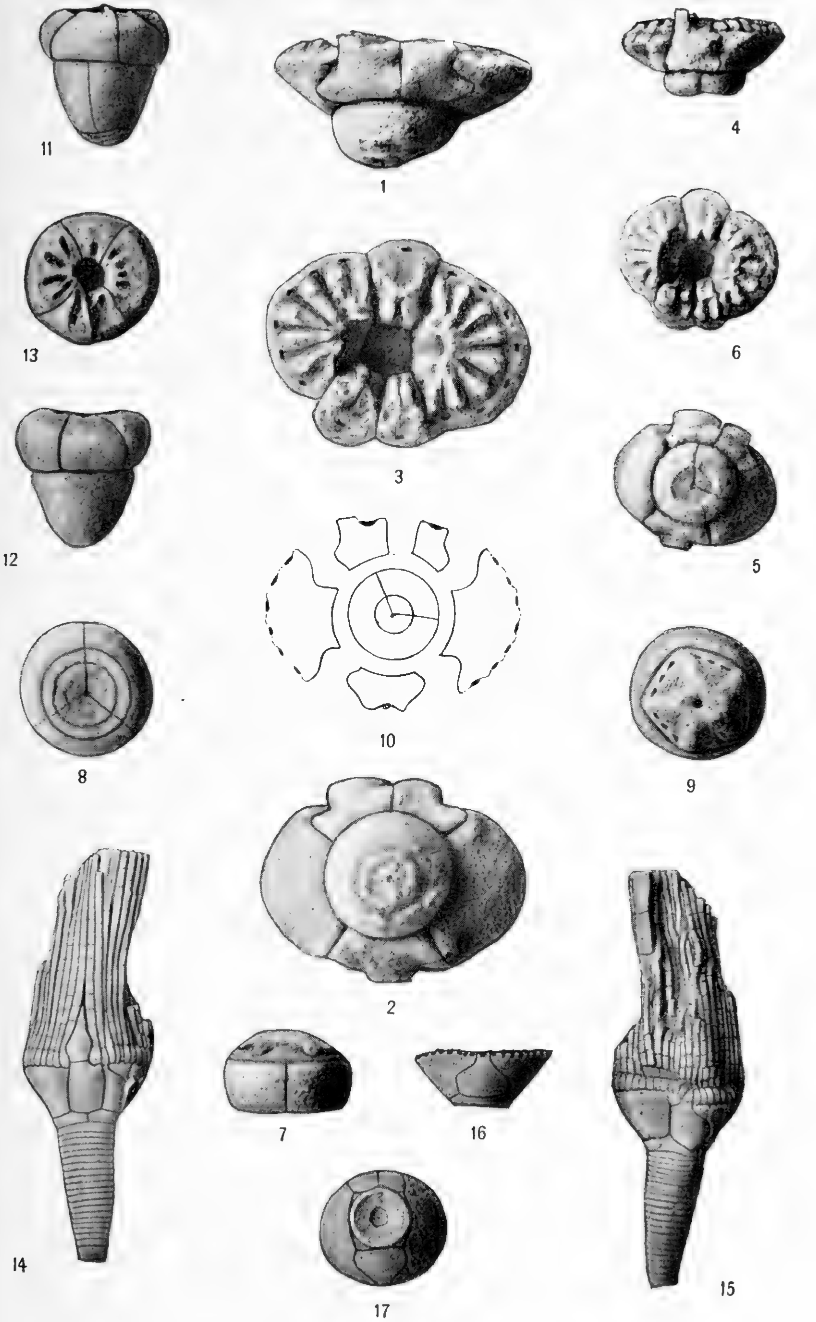
14. A nearly complete crown free from matrix, with 34 arms and proximal enlargement of stem; posterior view, showing anal plate, basal ring about one-fourth the height of cup, and a very distinct suture under r. post R. × $\frac{3}{2}$.

15. Left anterior view of same. × $\frac{3}{2}$.

16. A dorsal cup, showing the turbinate form, as contrasted with the hemispheric contour of *C. tennesseensis;* left anterior view. × 2.

17. Dorsal view of same; the obtusely angular area appearing at the middle of base corresponding to the infrabasal cone in specimens of *C. tennesseeae* is pushed inward to a different level, at which the lumen for the axial canal shows; no sutures can be seen in this, nor in the basal ring surrounding it. × 2.

Mississippian, New Providence shale; Button Mould Knob, Kentucky.



SPRINGER on the family CATILLOCRINIDÆ.

PLATE 2

PAGE

Catillocrinus tennesseeae (Troost) Shumard 26

Figs. 1, 2. Shumard's type, from Button Mould Knob, Kentucky; dorsal and ventral views; fig. 2 shows the cone of three divided infrabasals at the inner floor of the cup.

3, 4. Similar views of a maximum specimen from same locality also used by Shumard, having 58 arm openings; the IBB cone is plainly shown at the inner floor of the cup, but its dividing sutures are not visible; the position of the interbasal sutures connecting with the fused infrabasals, as deduced from other specimens, is indicated as they appeared at various angles and by transmitted light.

5. Troost's type from White's Creek Springs, Tennessee; dorsal view, showing division of basal ring into three unequal plates by sutures running from the space occupied by the infrabasals, here broken out; the position of two of the sutures is distinct, that of the third obscure, but visible in certain lights. In this specimen the surface is worn smooth by erosion.

6. A similar, but less eroded specimen with pentagonal IBB area vacant and succeeding BB divided by three sutures.

7. Interior view of part of fractured calyx having most of the basals broken away, leaving the infrabasal ring intact, perfectly outlined by the fracture, and plainly divided into three plates. $\times \frac{3}{2}$.

8. Outer (dorsal) view of same; the pustulose surface well preserved, but indistinct in the figure. $\times \frac{3}{2}$.

9. Specimen with base ground and polished, showing obscure outline of IBB, and five interbasal sutures; dorsal view.

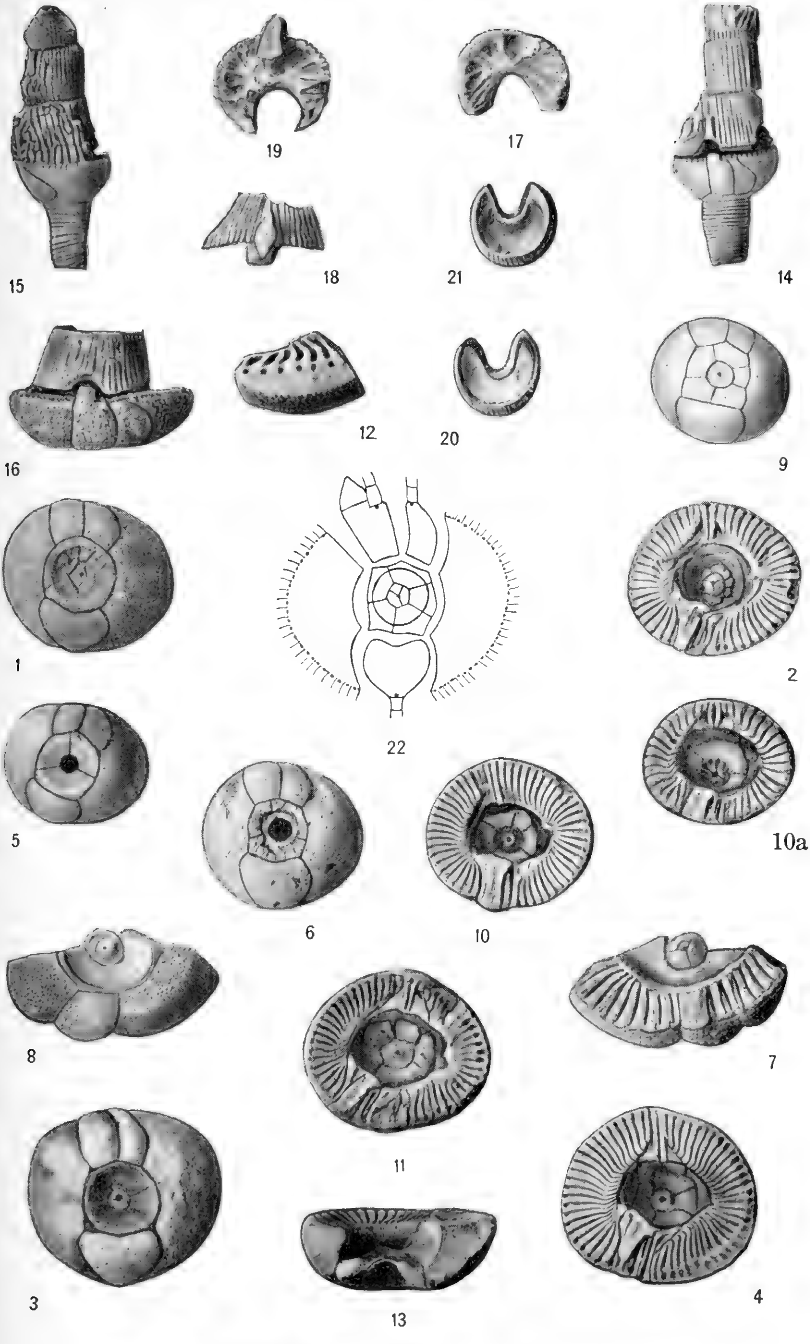
10. Ventral view of weathered specimen, showing the openings of dorsal canals at the arm facets, and their relation to the food grooves; also the extent, form and proportions of the raised process.

10a. Ventral view of smaller specimen with the infrabasal cone well defined.

11. Similar view of another large specimen, showing further details; the dorsal canals are seen passing inward under the floor of the food grooves. Division of basals into more than three plates is indicated in this and figure 10, not with complete regularity, but exactly as the inner floor of the calyx appeared to the artist without suggestion.

12. Section of radial transverse to the dorsal canals, showing their entrance below the level of the food grooves. $\times 2$.

13. Vertical section of dorsal cup, to show the great thickening at upper margin of radials contrasted with the extreme thinness of the base. $\times \frac{3}{2}$.



SPRINGER on the family CATILLOCRINIDÆ.

Catillocrinus tennesseeae (Troost) Shumard—*Continued*

14. Posterior view of specimen with part of stem, and anal tube (slightly displaced) having the longitudinal imprint of the slender arms; shows the raised process on r. post. R, and curved notch in first tube plate for reception of anal plate.
15. Left posterior view of same, with remnants of arms.
16. Posterior view of dorsal cup, with process on r. post. R, and a first tube plate in position notched for the anal plate, which is here wanting; to show the relation of these plates; strong pustulose surface shown, visible under a magnifier.
17. Proximal face of same tube plate, showing the radiating furrows facing the food grooves on dorsal cup.
18. A similar tube plate with the elongate anal plate attached in position interlocking with the notch.
19. Proximal, or under, side of same plate, showing the radiating furrows corresponding to food grooves on upper face of radial.

20, 21. Proximal and distal views of a higher tube plate, showing the crescentic cross section, and the large ligament fossae on both faces.

22. Diagram of calyx plates constructed from the specimens figured.
    All Mississippian New Providence shale; Button Mould Knob, Kentucky, and White's Creek, Tennessee.

Plate 3

PAGE

Catillocrinus wachsmuthi Meek and Worthen 26

Fig. 1. A nearly complete crown, with proximal enlargement of stem; from right anterior radius; the great length of the slender arms is shown, and the anal tube is exposed near the distal end.

2. A crown with 39 arms very perfectly preserved to nearly half their probable height, and exposing the massive tube; right posterior view, showing the elongated, pointed anal plate surmounting the raised process on r. post. R. × 2.

3. Cross section at fractured distal end of same specimen, showing the massive crescentic tube surrounded by the delicate arms. × 2.

4. A specimen in which the tube has been exposed from its origin, somewhat displaced at the base; left posterior view, showing in side view the anal plate interlocked with the lower tube plate, followed by a narrow, keel like projection. × 2.

5. Posterior view of part of same, showing relation of the narrow anal plate to adjoining structures. × 2.

6. A smaller specimen with 24 arms; posterior view showing elongate anal plate in position. × 2.

7. Basal view of same specimen, showing three well-defined interbasal sutures meeting at the axial canal. × 2.

8. Posterior view of another specimen with about 25 arms; stem omitted. × 2.

9, 10. Left anterior and basal views of calyx of a fractured specimen in which one basal plate is detached at its bounding sutures, and the suture between the other two is distinct, showing beyond question the division of the base in this species into three plates. × 2.

11. Diagram of calyx constructed from the foregoing specimen.

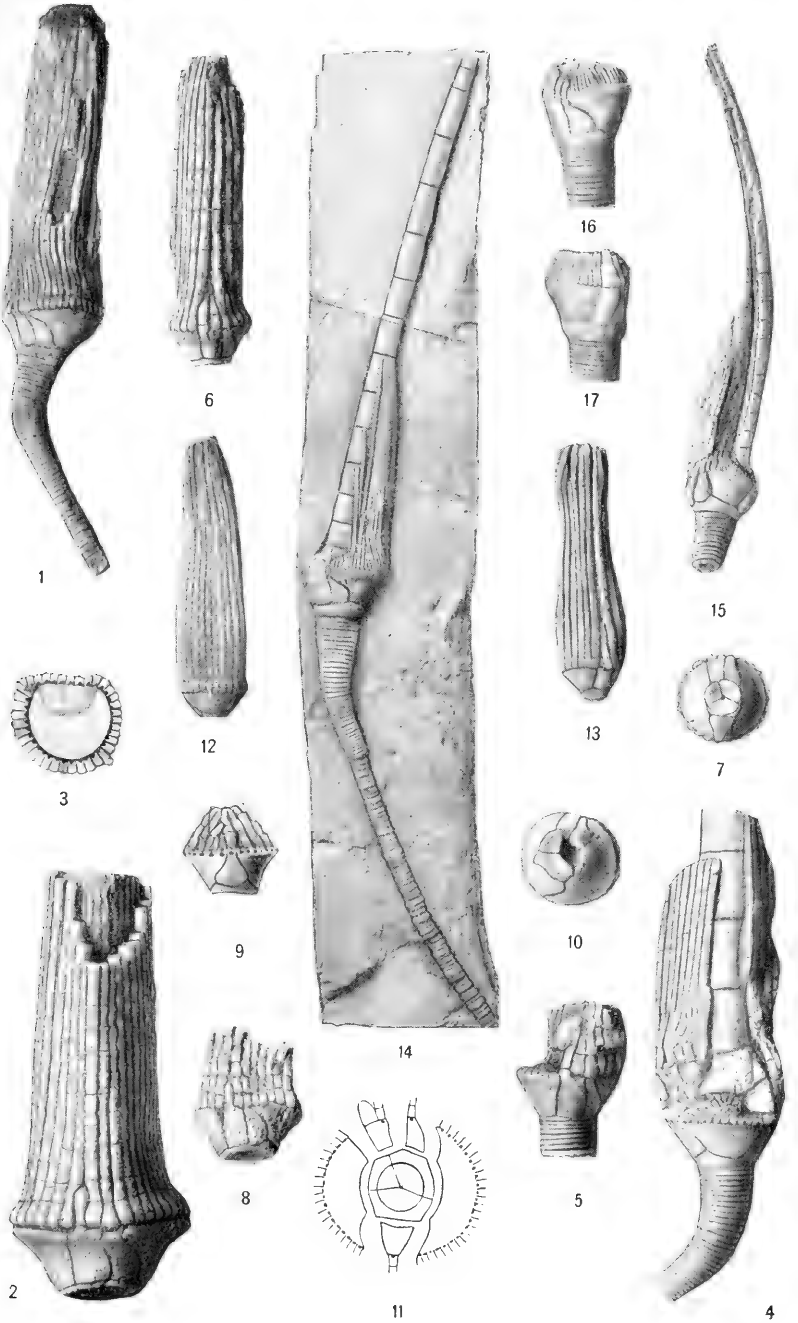
All Mississippian, Upper Burlington limestone; Burlington, Iowa.

Catillocrinus shumardi n. sp 27

12. A crown with nearly complete arms, anterior view. × 2.

13. Right posterior view of another specimen; has raised process on r. post. R, and three interbasal sutures—not well shown in the figure. × 2.

Mississippian, Keokuk limestone, lower horizon; Indian Creek, Indiana.



SPRINGER on the family CATILLOCRINIDÆ.

Catillocrinus bradleyi Meek and Worthen...................... 27

14. A specimen with anal tube almost complete, right posterior view, showing the tube rising directly from r. post. R, slightly displaced so that the anal plate is not shown; some of the extremely delicate arms (of which there are about 40 in all) are preserved, and the stem characters are well shown. On another specimen with calyx of the same size the complete stem is attached, about 37 cm. long, ending in a narrow point, with a few scattering cirri.

15. Left posterior view of another specimen with long tube, and short remnants of thread-like arms, the hollow side of the tube being seen; the basal ring is nearly one-third the height of the cup.

16, 17. Two calices with parts of arms and stem attached; l. ant. and post. views, showing the anal plate at same level as arms, directly following r. post. R, without any raised process. $\times \frac{3}{2}$.

Mississippian, Keokuk limestone, upper horizon; Crawfordsville, Indiana.

PLATE 4

FIG. 1. A nearly complete crown with proximal part of stem, posterior view; showing the great length and delicacy of arms, with tube extending to their distal ends. × $\frac{3}{2}$.

2. The tube in another specimen seen for almost its entire length, with remnants of arms at lower part—the calyx being lost. × $\frac{3}{2}$.

3. Anterior view of a very small specimen with 13 arms, and delicate stem. Calyx was detached from matrix and arms counted. × $\frac{3}{2}$.

4. Specimen with calyx plates displaced, showing small size of arms.

5. Specimen with calyx and part of arms detached from matrix, posterior view; showing full contour of calyx, strong suture under r. post. R, and anal plate at same level as arms, with no raised process at outer margin. × 3.

6. The same in original condition, from anterior radial. × 3.

7. The same, basal view of calyx, showing division into 3 plates. × 3.

8. Diagrammatic view of same, showing form and proportions of plates.

9, 10, 11. Posterior, anterior and basal view of similar detached specimens in which the calyx structures are well shown. × 3.

12. The type, from specimen in Illinois State Museum.

Nos. 1 to 12 from Monroe County, Illinois.

13, 14. Anterior and right anterior radial views of specimens showing details of arms. × $\frac{3}{2}$.

15. Similar specimen showing the extremely narrow left anterior radial. × $\frac{3}{2}$.

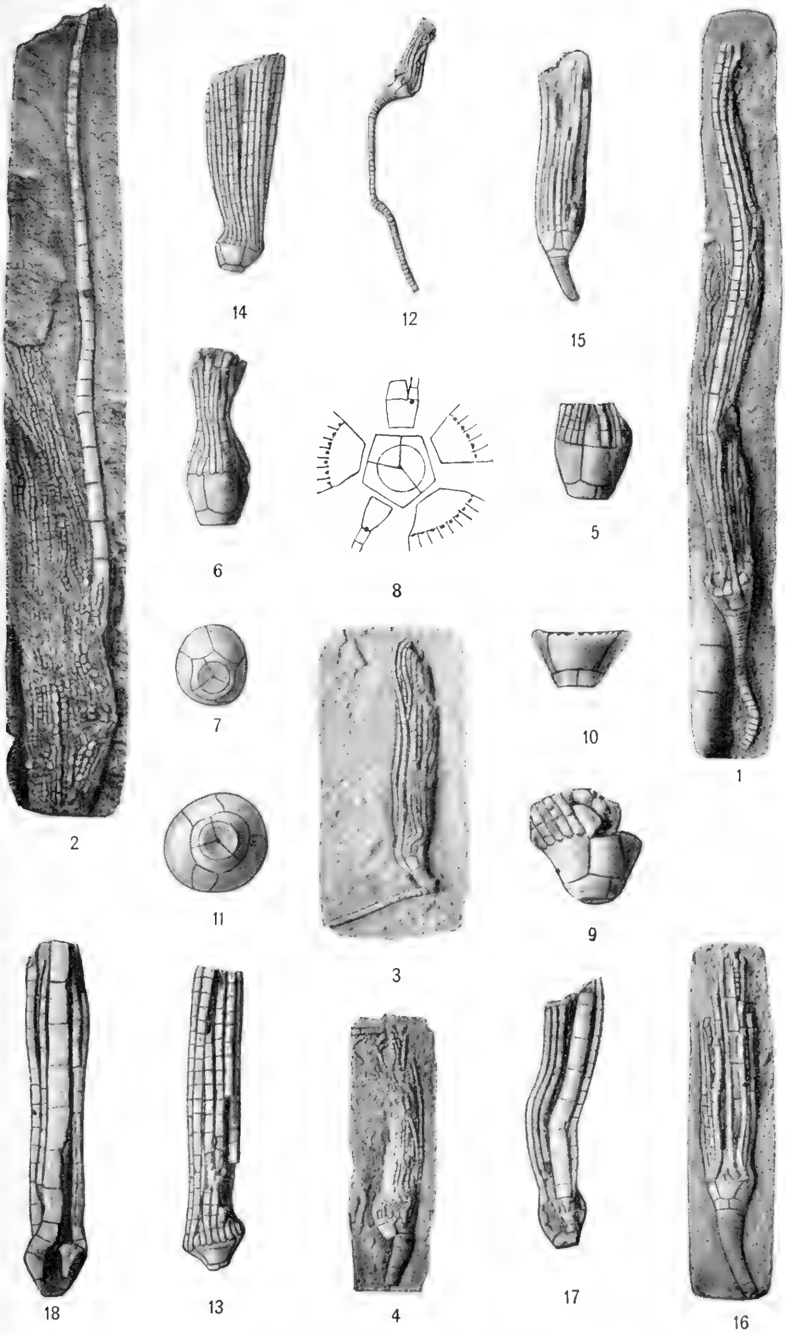
16. Anterior view of specimen with stem enlargement and calyx plates well shown; also the hollow side of tube. × $\frac{3}{2}$.

17. Posterior view showing the rounded side of tube; the two basal plates have been detached at their sutures, leaving one of the three remaining in place. × $\frac{3}{2}$.

18. Lateral view showing tube from its origin on r. post. R. × $\frac{3}{2}$.

Nos. 13 to 18 from Huntsville, Alabama.

Mississippian, all from lower part of Chester, Illinois and Alabama.



SPRINGER on the family CATILLOCRINIDÆ.

Plate 5

PAGE

Synbathocrinus wachsmuthi Meek and Worthen 19

Fig. 1. A specimen showing the heavy arms, with the anal tube passing up between them, distinguished by its smaller size and longer ossicles.

2. Posterior view of specimen with arms partly removed, showing the anal plate in position. $\times \frac{3}{2}$.
3. Lateral view of same, showing course of the tube plates following the anal; for comparison with figures 4 and 5 of plate 3; it shows also the ventral processes of the radials surmounted by the pyramid of oral plates. $\times \frac{3}{2}$.
4. Fragment showing grooved anterior side of anal tube plates contrasting in size and proportions with arm plates at same level. $\times \frac{3}{2}$.
5. Ventral view of calyx; showing the great thickening of the radials, their large muscle fossae, the groove leading to the anal tube, and the linear openings of the dorsal canals. $\times \frac{3}{2}$.
6. Basal view of same, showing division of basals. $\times \frac{3}{2}$.
7. General aspect of a small specimen with complete arms.

Mississippian Lower Burlington limestone; Burlington, Iowa.

Synbathocrinus wortheni Hall 19

8. A characteristic specimen from the Upper Burlington limestone; Burlington, Iowa.

Synbathocrinus dentatus Owen and Shumard 19

9. A maximum specimen of this large species, with arms complete; the anal tube, extending to nearly the full height of the arms, is readily seen in the specimen lying close under the left posterior arm, but is obscured by shadow in the figure.
10. A very young specimen from the same layer, with arms consisting of only about 10 brachials.

Mississippian, Upper Burlington limestone; Burlington, Iowa.

Synbathocrinus robustus Shumard 19

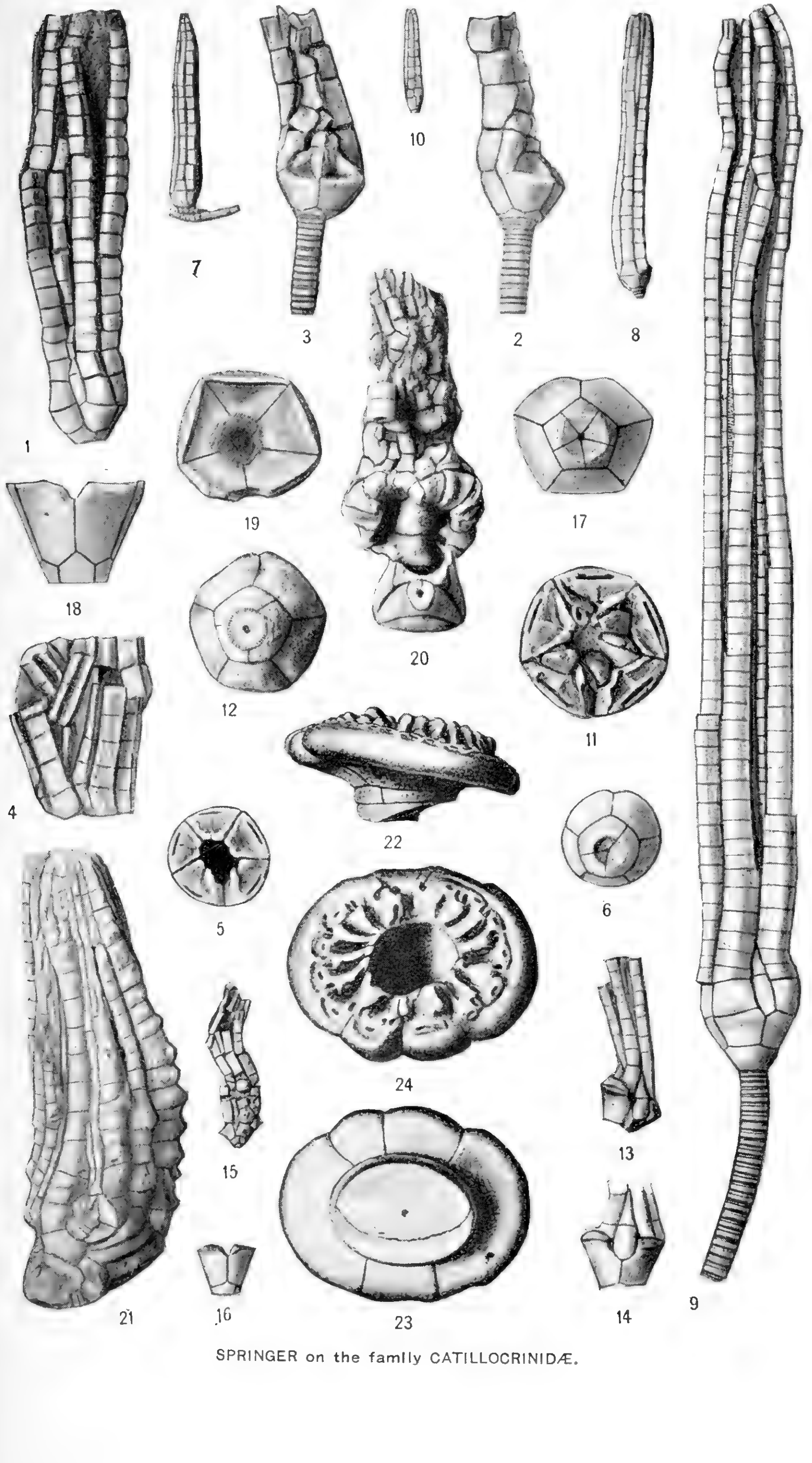
11. Ventral view of calyx showing thickened radials, wide arm facets, strong ventral processes, muscle fossae, groove at anal side, and linear openings of dorsal canals.
12. Basal view of another specimen.

Mississippian, New Providence shale; White's Creek, Tennessee.

Synbathocrinus hamiltonensis n. sp 29

13. The holotype, showing radials deeply notched for the anal plate.
14. Posterior view of calyx of same, showing the anal structures in better detail. $\times \frac{3}{2}$.

Middle Devonian, Hamilton; Bellona, New York.



SPRINGER on the family CATILLOCRINIDÆ.

PAGE

Synbathocrinus onondaga n. sp. 29

15. A small specimen from the Onondaga formation at Louisville, Kentucky, being the earliest known occurrence of the genus.
16. Posterior view of calyx of another specimen, showing form and proportion of plates. × 3/2.
Middle Devonian.

Phimocrinus americanus n. sp. 30

17. Basal view of holotype, showing division of base into five plates. × 3/2.
18, 19. Posterior and ventral views of same, the latter showing the absence of the great thickening of the distal face of radials. × 3/2.
Lower Devonian, Linden formation; Benton County, Tenn.

Deltacrinus dactylus (Hall) 19

20. Posterior view of a specimen showing the beginning of the massive anal tube.
Mississippian, Upper Burlington limestone; Burlington, Iowa.

Deltacrinus nodosus (Hall) 19

21. Specimen with calyx partly broken away, showing the heavy anal tube extending to full length of arms.
Mississippian, Keokuk limestone; Indian Creek, Indiana.

Paracatillocrinus granulatus Wanner 29

22. Lateral view, showing strong slant of calyx from vertical axis of stem. × 5/2.

Paracatillocrinus ellipticus Wanner 29

23, 24. Basal and ventral views, for comparison with *Catillocrinus*. × 5/2.
The last two Permian (?); Island of Timor, Dutch East Indies. The figures are copied from Wanner, Taf. XCVI, figs. 1*b*, and 4*b*, *c*.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 76, NUMBER 4

REPORT ON COOPERATIVE EDUCATIONAL AND RESEARCH WORK CARRIED ON BY THE SMITHSONIAN INSTITUTION AND ITS BRANCHES

(Publication 2719)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
JULY 28, 1923

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

REPORT ON COOPERATIVE EDUCATIONAL AND RESEARCH WORK CARRIED ON BY THE SMITHSONIAN INSTITUTION AND ITS BRANCHES

CONTENTS

I. HISTORICAL AND GENERAL

The announced policy of the Smithsonian Institution has ever been one of cooperation. In the plan of organization as given in the first annual report (1847), "It is proposed—(1) To stimulate men of talent to make original researches, by offering suitable rewards for memoirs containing new truths; and (2) To appropriate annually a portion of the income for particular researches, under the direction of suitable persons," the "suitable rewards" to consist of money, medals, etc., offered for original memoirs on all branches of knowledge. As examples of objects for which such appropriations might be made, the following was given:

(1) Systems of extended meteorological observations, for solving the problem of American storms.

(2) Explorations in descriptive natural history, and geological, magnetical, and topographical surveys, to collect materials for the formation of a Physical Atlas of the United States.

(3) Solution of experimental problems, such as a new determination of the weight of the earth, of the velocity of electricity and of light; chemical analyses of soils and plants; collection and publication of articles of science, accumulated in the offices of government.

(4) Institution of statistical inquiries with reference to physical, moral, and political subjects.

(5) Historical researches, and accurate surveys of places celebrated in American history.

(6) Ethnological researches, particularly with reference to the different races of men in North America; also, explorations and accurate surveys of the mounds and other remains of the ancient people of our country.

In the report for 1854 this point is again emphasized:

It is the policy of the Institution to furnish all the means in its possession to aid scientific research, and not to hoard up its treasures or confine their use to those who may be immediately connected with the establishment, or who may be supported by its funds. *Cooperation* and not *monopoly* is the motto which indicates the spirit of the Smithsonian operations.

And again:

With scarcely an exception, every exploring expedition of any magnitude has received more or less aid from the Smithsonian Institution. This has consisted in the supplying of instructions for making observations and collections in meteorology and natural history, and of information as to particular desiderata; in the preparation, in part, of the meteorological, magnetical, and natural history outfit, including the selection and purchase of the necessary apparatus and instruments; in the nomination and training of persons to fill important positions in the scientific corps; in the reception of the collections made, and their reference to individuals competent to report upon them; and in employing skillful and trained artists to make accurate delineations of the new or unfigured species. Much of the apparatus supplied to the different parties was invented or adapted by the Institution for this special purpose, and used for the first time, with results surpassing the most sanguine expectations.

It is apparent from these and other extracts that might be made from the annual reports that cooperation on the widest scale was, from the outset, the prevailing motive of the Institution. It is proposed in the following pages to give the result of recent investigations made with a view of ascertaining how far these early promises had been carried out.

II. THE SMITHSONIAN ORGANIZATION

The following named organizations are conducted under the administration of the Smithsonian Institution: The United States National Museum; the Bureau of American Ethnology; the National Gallery of Art, including the Freer Gallery of Art; the National Zoological Park; the Astrophysical Observatory; the International Exchange Service; and the International Catalogue of Scientific Literature.

III. COOPERATION: DEFINITION OF THE TERM

By cooperation, as here used, is understood the act of assisting in any way the advancement of knowledge, let it be through the direct solution of a problem, or indirectly through supplying aid, funds, or material, or the giving of any form of personal services.

For purposes of clear presentation the matter may be considered in the following order:

(1) By conference and advice through correspondence and otherwise.

(2) By furnishing materials (a) for investigation, as gift or loan, (b) for teaching purposes.

(3) By furnishing facilities.

(4) By furnishing personal assistance, expert or otherwise.

(5) By furnishing funds.

(6) By furnishing means of publication.

(1) Cooperation through Advice and Correspondence

It is a safe affirmation that scarcely a day has passed since the organization began actively to function but that letters are received from, or personal interviews held with, those who wish aid or advice on matters relating to some one of the many subjects involved. The full importance of this work cannot be estimated, but as years go on it has become of ever increasing magnitude. The following taken from the ninth and tenth annual reports of the Secretary of the Institution (1854-55) show the early stand of the Institution in this line of work:

Correspondence.—During the past year the Institution has received a large number of communications asking information on a variety of subjects, particularly in regard to the solution of scientific questions, the names and characters of objects of natural history, and the analysis of soils, minerals, and other materials which pertain to the industrial resources of the country. Answers have in all cases been given to these inquiries, either directly by the officers of the Institution, or by reports from the Smithsonian colaborers. Very frequently certificates are requested as to the value of certain minerals, with a view to bring them into market; but in these cases the inquirers are referred to certain reliable analytical chemists, who make a business of operations of this kind. The information procured and given at the expense of the Institution is such as relates to the general diffusion of knowledge, and not to that which may immediately tend to advance the pecuniary interest of individuals. Requests are often also made to have experiments instituted for testing proposed applications of science to the arts; and provided these can be tried with the apparatus of the Institution and the results which may flow from them are to be given to the public without the restriction of a patent, the request is granted.

And again:

The correspondence during the last year has been more extended than that of any preceding period. The character of the Institution becoming more widely known, the number of applications for information relative to particular branches of knowledge has been increased. The correspondence relates to the exchanges, the collections, the publications, the communication with authors and the members of commissions to which memoirs are submitted, answers to questions on different branches of specimens of natural history, geology, etc.; also explanations of the character of the Institution, the distribution of its publications, its system of meteorology, etc.

And yet again:

As the collaborators of the Institution generally reside at a distance, the business with them is principally carried on by mail. The same is also the case in regard to all the exchanges and consequently the record of nearly all the transactions of the Institution is contained in the correspondence. Besides those relating to official business, hundreds of letters are received during the year, containing inquiries relative to the various subjects on which the writers desire information. If these cannot be immediately answered without much research, they are referred to collaborators who are experts in the various branches of knowledge, and who can readily supply information in regard to subjects within the range of their special studies. (Annual Report, 1868, p. 51.)

In previous years requests have frequently been received from foreign governments, especially those of Japan and China, and of Central and South America, for the selection of persons to carry on certain operations, particularly those relating to engineering and mining geology, nearly every year bringing at least one call of this character. To this the year 1879 furnished no exception, the Government of Salvador, through the American minister, Mr. George Williamson, having asked to be supplied with an experienced geologist to explore the recently discovered gold fields of the state. Of course in such cases the advice of experts is always solicited, and several of these uniting on the name of Mr. Goodyear, a resident of California, and formerly connected with the geological survey of that state, he was selected for the mission in question, and has already entered upon his duties (Annual Report, 1879, p. 57.)

(2) Cooperation through Furnishing Materials

This is an important and ever-increasing phase of the work of the Institution. It appears that as early as 1849 the regents made an appropriation for the purchase of a telescope for the use of the

Gillis Astronomical Expedition to Chile, and in the report for 1854 the purchase is announced of four entire sets of apparatus for determining the direction and intensity of magnetic force which were lent to various observers, including those of the Grinnell Expeditions of 1850-55 and the U. S. Coast Survey. "It is the purpose to keep these instruments constantly in operation for the purpose of comparing results with other observations of a similar character."

Coopération with meteorologists the world over was one of the earliest undertakings. In the second annual report of the Institution for 1848 (1849) it is stated that the sum of $1000.00 was appropriated for the commencement of a series of observations, particularly with reference to the phenomena of storms. It was proposed to enlist the services and cooperate with voluntary private and public individuals and institutions, including the United States Navy.

With the instruments owned by private individuals, with those of the several military stations, and with the supply of the deficiency by the funds of the Smithsonian Institution, it is believed that observations can be instituted at important points over the whole United States, and that, with the observations which we can procure from Mexico and the British possessions of North America, data will be furnished for important additions to our knowledge of meteorological phenomena. As a beginning to this extended system, six sets of instruments have been forwarded to the coast of Oregon and California, for the purpose of establishing periodical observations on the western side of the Rocky Mountains. Also a set has been forwarded to Bent's Fort, and another to Santa Fe. Circulars have been prepared and will shortly be issued for the purpose of ascertaining the number and locality of all those who, with or without instruments, are willing to join in the enterprise.

Obviously, here was laid the foundation of the United States Weather Bureau as it exists today.

It is not alone through furnishing apparatus that cooperation is carried on. In the form of gifts and loans for the purpose of research and study, thousands of specimens are annually distributed to investigators and students the world over. "Applications for such assistance," wrote Professor Baird in his report for 1854, "are constantly being received, and always met with all possible promptness, so that scarcely any natural history monograph or memoir of any extent has been published in this country within a year or two which has not been indebted in this way to the Institution."

(3) Cooperation through Furnishing Facilities

"It is a part of the plan [*i. e.*, of the Smithsonian Institution] to give encouragement and assistance to original investigators, and persons who visit Washington for the purpose of studying the collection are furnished with all the facilities which the Institution can afford." (10th Annual Report, 1855.) These "facilities" included not merely access to the collections, library, and laboratories, but in numerous instances the early investigators were actually given living rooms in the building. Within recent years the last-named practice has been discontinued, but the others mentioned endure. As early as 1855 the chemical laboratory of the Institution was utilized by Dr. J. L. Smith in examination of minerals, and by the Treasury Department in investigations relative to the kinds of molasses imported into this country.

(4) Cooperation through Personal Assistance, Expert and Otherwise

Aid in the identification of material is perhaps of all forms of cooperation the most common. A large share of these requests come from individuals, and while time-consuming, leave no tangible results for permanent records. Those from museums, scientific workers, and departments of the Government require expert knowledge of a much higher standard, and often find their way into the printed reports. A very large amount of work of this nature is done in cooperation with the U. S. Geological Survey, Bureau of Fisheries, and Department of Agriculture. Decisions relative to the establishment of National monuments, and to materials for Government structures are often asked. As long ago as 1856, Professor Henry was appointed to cooperate with Colonel Totten, A. J. Downing, the Commissioner of Patents, Prof. A. D. Bache of the Coast Survey, and Captain Meigs, to examine and report on the marble submitted for use in the Capitol extension, and for over 20 years he cooperated with the Lighthouse Service in the investigation of fog signals and other aids to navigation. Prof. S. F. Baird, while Assistant Secretary of the Institution, in 1871, began the long series of cooperative studies on the food fisheries of the country which resulted in the establishment of the U. S. Fish Commission, to which he gave his services without other salary than was attached to his duties as Secretary until his death. Other instances are given in detail in another section of this report.

(5) Cooperation by Supply of Funds

The income from the Smithsonian Institution endowment has never been sufficient to allow financial grants of large size. As early as 1855 it is stated:

> In anticipation of the great fair in Chicago of the Illinois State Agricultural Society, it was proposed to secure and exhibit full collections of the natural history of the State on that occasion. Accordingly, Mr. Robert Kennicott was selected by the Society to travel throughout Illinois, especially along the lines of the Illinois Central Railroad, and not only to make collections himself, but to instruct the employees of the railroad company and others, so as to enable them to assist in the work. Aided by a small appropriation by the Institution, in addition to the facilities furnished by the society and the railroad company, Mr. Kennicott collected in a few months the finest cabinet of Illinois specimens ever brought together.

The custom thus inaugurated has been followed out with increasing magnitude, involving the Philadelphia Centennial of 1876, the Chicago Exposition of 1893, and, on a smaller scale, those of Atlanta, Ga.; New Orleans, La.; Buffalo, N. Y.; Charleston, S. C.; Cincinnati, O.; Seattle, Wash.; Omaha, Neb.; St. Louis, Mo.; Portland, Oreg.; and San Francisco, Calif. For most of these, special grants of funds were appropriated by Congress.

With the endowment of the Institution through private bequests, other allotments have been possible. By grants from the Hodgkins Fund the Institution has been able to cooperate with Dr. Leonard Hill and others in investigations on the influence of the atmosphere on human health; with Wolfgang Ritter on the flight of insects; E. W. Scripture on the construction of a vowel organ; with C. G. Abbot on Arequipa pyrheliometry, the pyranometer, and solar variability; with Anders Ångström on atmospheric radiation; with E. Duclaux on atmospheric actinometry; with J. B. Cohen on the atmosphere of towns; with Carl Barus on atmospheric nucleation and ionized air; with Lord Rayleigh and W. Ramsay in their investigations on argon; with H. de Varigny on air and life; with O. Lummer and E. Pringsheim on the ratio (x) of specific heats; with V. Schumann on the absorption and emission of air for certain light wave lengths; with M. W. Travers and others on the attainment of low temperatures, etc.

(6) Cooperation on Publications

No insignificant proportion of the funds and energies of the Institution have been devoted to the publication of works of scientific and educational value, but from the sale of which no satisfactory financial return could be anticipated. This form of cooperation, inaugurated in 1847 and bearing its first fruit in the publication of Squier and Davis' *Ancient Monuments of the Mississippi Valley* (1848), has continued until the present day, and, as a result, a very considerable proportion of the papers comprised in the 35 quarto volumes of the Smithsonian Contributions to Knowledge, the 74 volumes of Miscellaneous Collections, the 63 volumes of Proceedings, and upward of 120 Bulletins are by writers not connected, or but indirectly connected with the Institution.

IV. SPECIFIC INSTANCES OF COOPERATION BY THE SMITHSONIAN INSTITUTION AND ITS BRANCHES

The following annotated list of some of the principal cooperative operations carried on is here given in order that their magnitude and often involved character may be better understood. Owing to the somewhat complex nature of many of them, a strict form of classification has been found impossible, though as a general rule they are arranged by departments or divisions. It may be further stated that while a very considerable proportion are wholly one-sided, the Institution profiting little, if at all, thereby, there are others in which, through the enrichment of the collections, the National Museum profits largely.

The National Museum

This branch of the Institution is naturally brought into active cooperation with practically all divisions of the National government, with those of foreign countries, with public and private museums and other educational institutions, and with individual students of the sciences. At the present moment (1923), facilities for the storage of collections, office and work rooms, are afforded to the following: The paleontologists and paleobotanists of the Geological Survey occupy 13 double rooms, comprising 15,600 square feet of floor space, and utilize upward of 15,000 standard drawers; to the Biological Survey is assigned 7,019 square feet of floor space, with facilities for storage for 126,240 specimens; and to the entomologists of the Department of Agriculture, 9 rooms, aggregating 5,539 square feet of floor space.

With limited finances the Museum is unable to inaugurate regular lecture courses, but all governmental agencies and all scientific and educational societies have the free use of its auditorium and the adjacent rooms for congresses, lectures, etc. Space is also furnished for special exhibits of scientific or educational importance.

A line of cooperation, the value of which, while great, it is impossible to estimate, is the distribution to schools, colleges, and private workers, of specimens of all kinds to aid in their studies. The report of the Institution for 1867 states that 249,233 specimens of all kinds had been distributed up to that early date. During the 46 years from 1876 to 1922, there were distributed upward of 771,000 specimens, bringing the total number to upward of 1,000,000.

Cooperation with educators and students does not end with the furnishing of materials for their natural history and other studies. The exhibition collections are all designed with the view, not merely to attract the public, but to aid the student, and members of the staff of certain departments frequently conduct classes through the halls explaining the uses of the objects exhibited. The study series are always at the service of accredited students, and the publications are supplied free of cost. Lectures are delivered before schools or other organizations, and have also been prepared for delivery throughout the country in cooperation with the Young Men's Christian Association and like organizations.

The following more detailed instances of cooperative work will show to an extent the wide range and varied nature of the projects undertaken by the Museum.

DEPARTMENT OF BIOLOGY

North Pacific Fur-Seal Investigations.—The cooperation of the Museum with the various Government agencies concerned in the investigation of the North Pacific fur-seals and fur-seal industry dates back to 1882, when a project jointly undertaken by the National Museum, the U. S. Fish Commission, and the U. S. Signal Service was carried into effect by sending Dr. Leonhard Stejneger to the Commander Islands, a group of fur-seal islands belonging to Russia and situated off the coast of Kamchatka. He remained 18 months on the islands, surveying the rookeries, studying the habits of the seals, managing a third-class meteorologic station, and making large collections of the animals and plants for the Museum.

In 1895 the U. S. Fish Commission, on account of the tremendous inroads on the fur-seal herds caused by pelagic sealing, desired a thorough investigation of the whole question, and for that purpose obtained the detail of Drs. F. W. True and Leonhard Stejneger, both of the National Museum, the former to visit the Pribilof Islands, the latter the Commander Islands. The whole summer was spent on the islands, and upon their return, each submitted a voluminous report, which was published.

In 1896, Messrs. F. A. Lucas and Leonhard Stejneger, both of the National Museum, were appointed members of the Fur-seal Investigation Commission, which, under Dr. David S. Jordan as Commissioner in charge, was intrusted by the U. S. Treasury Department with studying and reporting upon the whole fur-seal problem with special reference to the effect of the award of the Paris Tribunal on the rehabilitation of the seal herds and the regulation of pelagic sealing. Mr. Lucas remained during the entire summer with the Commission on the Pribilof Islands, taking the census of the rookeries, studying the habits of the seals both on shore and at sea, investigating the problem of the abnormal mortality of the young, etc., while Dr. Stejneger again proceeded in the Fish Commission S. S. *Albatross* to the Commander Islands where he inspected the rookeries and supplemented his observations of the previous year. From there he continued in the *Albatross* to the Kuril Islands of Japan, in search of seal rookeries which might possibly have escaped the destruction inflicted upon them by raiders and pelagic sealers. He then proceeded to Robben Island, the Russian seal island, in the Okhotsk Sea, off the east coast of Sakhalin, which was inspected, mapped, and photographed.

The Commission was continued during the season of 1897, but the investigations were conducted that year under the auspices of the Department of State, and in collaboration with a similar commission from Great Britain. Messrs. Lucas and Stejneger were again detailed and spent the season, the former investigating the Pribilof herd, the latter the Commander Island seal industry. The results of this cooperation was embodied in the four-volume report published in 1898-1899 by the U. S. Treasury Department under the title "The Fur Seals and Fur-seal Islands of the North Pacific Ocean."

As the seal protection treaty of 1911 may become abrogated in 1925 if denounced 12 months before by any of the four contracting powers, the Department of Commerce desired to obtain first-hand information as to the status of the fur-seal herds of the Commander Islands and Robben Island. In the spring of 1922, the Department therefore requested the Museum to detail Dr. Stejneger for the purpose of inspecting the North Pacific fur-seal rookeries. He was consequently attached to the party accompanying Mr. C. H. Huston, the Assistant Secretary of Commerce, on his tour of investigating the fisheries of Alaska and far eastern Asia, which left Seattle, Washington, on June 20, 1922, in the Coast Guard cutter *Mojave*. During this cruise he visited the Pribilof Islands, the Commander Islands, and Robben Island, returning to Washington by way of

Japan on September 18. A preliminary account of his findings has been submitted, and the elaborate report is now in preparation.

It thus appears that the Department of Biology for more than 40 years has cooperated with the various Government departments which have had the investigation of the important fur-seal problem in hand, having had members of its staff detailed for the purpose during six seasons, viz.: in 1882, 1883, 1895, 1896, 1897, 1922. Moreover, after their return, they prepared elaborate reports which are among the most valuable contributions to the literature on the subject. The numerous publications on the history of the Asiatic Seal Islands, due to the cooperation of the Museum, form practically the only available information about these islands which are of so great importance both scientifically and economically.

Investigations on the life history of the lobster.—Under the date of May 20, 1918, the Department of Commerce requested the detail of a member of the Museum force to the Bureau of Fisheries for the purpose of investigating the life history of the spiny lobster of the Pacific Coast. In this connection it was stated that, while the spiny lobster on the west coast possessed considerable economic importance as an article of food, it had been "so steadily declining in numbers on the coast of California that the market supply was chiefly by importation from the coast of Mexico, and that an elucidation of the life history of the form would undoubtedly be a proper step in arriving at and termination of the measures of protection or propagation necessary to insure the conservation of the species."

This detail became effective for three months beginning August 1, during which period important collections were made, and several interesting facts established. Brief preliminary reports of the work were published, but the final summary is not yet completed.

The Geographic Society of Baltimore Expedition to the Bahamas.—This expedition was conceived and conducted by Mr. George B. Shattuck, then of Johns Hopkins University, and sailed from Baltimore on June 1, 1903. Among the Government and other experts detailed for the purpose of studying the natural history, soil, sanitation, diseases, etc., of the islands were Messrs. B. A. Bean and J. H. Riley of the National Museum. The cruise extended over a period of nearly two months, but opportunities for collecting natural history specimens at individual landings were very brief. A general report upon the expedition was published by the Society, including a list of all the birds recorded from the Bahamas, contributed by Mr. Riley. The Museum paid for the subsistence of its two representatives.

Harriman Alaska Expedition.—By invitation of the late Edward H. Harriman, a number of naturalists joined him in an expedition to Alaska in the summer of 1899. The National Museum was represented by Dr. W. H. Dall, Mr. F. V. Coville, and Mr. R. Ridgway, who made collections in their respective fields. From Seattle the party proceeded to various points on the coast of Alaska, making occasional trips inland, and also touched at Hall Island, St. Lawrence Island, and St. Matthew Island in Bering Sea, stopping also at Plover Bay, Siberia. The expedition was not operated on a schedule planned for making natural history investigations, and stops at most of the points were quite brief, but Mr. Ridgway was able to secure 319 specimens of birds and a series of eggs, from various localities. No report on these has been published, but records have been incorporated in various volumes, and one new form described.

Doctor Coville, assisted by other members of the expedition, made extensive collections of plants. These, supplemented by earlier collections in the National Herbarium, and by the results of subsequent field work by several Government departments, incidental to a study of the geography and natural resources of Alaska, have been studied critically by several botanists, and the final results brought together for publication as volumes 6 and 7 of the Harriman Alaska series, now under control of the Smithsonian Institution.

The Zoological Expedition of Dr. Theodore Lyman to the Altai Mountains, Siberia and Mongolia.—During the summer of 1912, by the invitation of Dr. Theodore Lyman, of Harvard University, the National Museum was enabled to participate, in cooperation with the Museum of Comparative Zoology, in a zoological expedition to the Altai Mountains of Siberia and Mongolia. The expedition was under the personal direction of Doctor Lyman, and the National Museum was represented by Mr. N. Hollister, assistant curator of mammals. The party left America in May and returned in September. From the last Russian outpost near the Mongolian border, Kosh-Agatch, the frontier range to the southward was explored for a month. The collecting was done chiefly on the Siberian side of the range, but expeditions were made to the Mongolian slopes for great game, and down to the Suok Plains, in the country of the Kirghiz. On the return trip, stops were made on the Chuisaya Steppe and in the heavily forested Altais between the desert and the great Siberian plains.

The collections of mammals were worked up by Mr. Hollister; the birds were studied by Doctor Bangs at Cambridge. The specimens were then divided between the National Museum and the Museum of Comparative Zoology.

General Survey of the Mexican Flora.—From 1897 to 1911, Dr. J. N. Rose, associate curator of the National Herbarium, carried on extensive botanical explorations in Mexico, in cooperation at different times with the New York Botanical Garden, the New York Aquarium, the U. S. Department of Agriculture, the Bureau of Fisheries, and the Mexican government, with a view to making known the diverse flora of that country. During this work, many thousands of plants were collected, hundreds of which were new to science and to the collections of the National Museum and of other institutions to which they were distributed.

Through the cooperation of the U. S. Department of Agriculture and the New York Botanical Garden, some of the more interesting forms were grown in greenhouses in Washington and New York. Many new species have been described, and important critical genera and groups revised by Doctor Rose, either alone or in collaboration with Dr. N. L. Britton, in various publications.

Study of the Cactaceae.—From 1912 up to the present time, Dr. J. N. Rose has been engaged with Dr. N. L. Britton, director-in-chief of the New York Botanical Garden, in an investigation of the Cactaceae of North and South America, a study begun several years previously, but since 1912 chiefly financed by the Carnegie Institution of Washington, with the cooperation of the New York Botanical Garden, the U. S. National Museum, and the U. S. Department of Agriculture. Besides the earlier Mexican exploration, field trips in northern, western, and eastern South America have yielded valuable material bearing on this project. The results of the investigation are being published by the Carnegie Institution of Washington in four large, profusely illustrated volumes, entitled "The Cactaceae." In this study the authors have had the valued cooperation of a large number of botanists and botanical collectors throughout the western United States and all tropical America, as well as of many institutions and special students of this family in Europe.

Exploration of northern South America.—In the early part of 1918, a cooperative plan of exploration in northern South America was entered into by the New York Botanical Garden, the Gray Herbarium of Harvard University, and the U. S. National Museum, for the purpose of obtaining through joint field work a better knowledge of the rich and varied flora of northern South America, and of bringing together well preserved herbarium material that would afford not only general information relating to the systematic botany of these regions, but would also provide exact basic information regarding many plants capable of yielding commercial timbers, drugs, oils, dye-stuffs, food-material, fibers, and other economic products whose sources are in many instances obscure or unknown. The investigation was planned to cover Ecuador, Colombia, Venezuela, the Guianas, and several adjacent Caribbean islands, regions in which no coordinated botanical exploration had ever been conducted, and from which material is urgently needed in connection with similar studies of the botany of the West Indies and Central America. In pursuance of the plan, several expeditions have gone into South America for the benefit of the three institutions mentioned.

Trees and Shrubs of Mexico.—In partial response to the pressing demand for a synoptical treatment of the woody plants of tropical North America, Mr. Standley has utilized the unrivalled Mexican collections of Pringle, Palmer, Rose, Purpus, and others in the National Herbarium in preparing a manuscript on the "Trees and Shrubs of Mexico." Botanists of several institutions have assisted in this work, and much aid has been rendered also by the Mexican government, chiefly in the transmittal of botanical material obtained during the biological survey of that country now in progress, all of this being submitted to the U. S. National Museum for identification. Similar material is being received through cooperation with several able Mexican botanists, notably Dr. C. Conzatti of Oaxaca City.

Flora of Central America and Panama.—Upon the practical completion of his manuscript upon the trees and shrubs of Mexico, Mr. Standley took up the project of preparing a synoptical treatment of the phanerogamic flora of all Central America and Panama. The collections from these regions in the National Herbarium, though large, are mainly from Guatemala, Costa Rica, and Panama. For the purpose of obtaining material from a part of the intermediate area, Mr. Standley was detailed to field work in Salvador, in December, 1921, and spent five months there and one month in eastern Guatemala, with funds provided by the cooperation of Prof. Oakes Ames, the New York Botanical Garden, the Gray Herbarium, and the U. S. Department of Agriculture, and with the hearty assistance of the Salvadorean government. An enumeration of the entire collection will be published jointly by Messrs. Standley and Calderon in Salvador under Government auspices.

In furtherance of this project additional field work is contemplated in Honduras, Nicaragua, Costa Rica, and Panama, official support of the undertaking being assured in several quarters.

Studies in West Indian Ferns.—During several months in three years, Mr. William Maxon, associate curator of the National Herbarium, collected pteridophyta extensively in Jamaica, in 1903 in company with Prof. L. M. Underwood of the New York Botanical Garden, in 1904 for the National Herbarium alone, and in 1920 in company with Mr. E. P. Killip on behalf of the National Herbarium, the New York Botanical Garden, the Gray Herbarium, the Field Museum, and the University of Illinois. The material thus assembled affords the basis of a descriptive volume on the pteridophyta of Jamaica, which will be published by the British Museum (Natural History) as one of the series on the Flora of Jamaica by Fawcett and Rendle.

North American Flora.—About twenty years ago the New York Botanical Garden undertook the publication of a descriptive work upon the flora of North America, intended to cover all the plants growing independently of cultivation in continental North America (including Panama), Greenland, and all but the southernmost of the West Indian islands. This work, entitled " North American Flora," is to be complete in 34 volumes. Botanists of many American institutions, including those of the National Herbarium, are cooperating in this work.

Biological Survey of the Panama Canal Zone.—Beginning in 1910, the Smithsonian Institution, with the assistance of several Government departments and outside institutions, undertook to sponsor a biological exploration of the Canal Zone and adjacent parts of Panama, the expenses of the field work being met by a special fund contributed by patrons of the Institution. For the botanical work Prof. H. Pittier and Dr. A. S. Hitchcock were detailed by the Bureau of Plant Industry, and Mr. William R. Maxon, by the National Museum. Partial results of the work have been published.

Flora of the District of Columbia.—In connection with a study of the local flora for 40 years past there has grown up at the National Herbarium a collection known as the District Herbarium, to which many students of local natural history have contributed. To replace Museum Bulletin 26, known as *Ward's Flora,* and long out of print, local botanists joined about ten years ago in an effort to prepare a new manual of the local flora. In all, about 25 individuals actively participated, mainly members of the staffs of the National Herbarium and the Bureau of Plant Industry. The outcome was the publication of the " Flora of the District of Columbia and Vicinity," under the editorship of A. S. Hitchcock and Paul C. Standley, dealing with the ferns and flowering plants of this region. Supplementary work, including similar treatment of the lower cryptogams, is under way.

Flora of the National Parks.—At the request of the National Park Service, Department of the Interior, Mr. Standley was detailed in the summer of 1919 to make a botanical survey of Glacier National Park, Montana, the expenses of the work being shared between the National Museum and the Park Service. The very large number of plants and plant photographs obtained have served as the basis of two reports, one a technical paper published as Part 5 of volume 22, Contributions from the U. S. National Herbarium, the other a profusely illustrated manuscript of a non-technical nature to be published eventually by the Park Service.

Flora of the Pacific Coast.—An illustrated Flora of the Pacific Coast (Washington, Oregon, and California), to appear in three or four large volumes, is being prepared under the direction of Prof. LeRoy Abrams, Department of Botany, Leland Stanford University, California. Messrs. William R. Maxon and A. S. Hitchcock have collaborated in this work.

Cooperation with the U. S. Department of Agriculture.—The relationship existing between the Department of Agriculture and the National Herbarium is naturally a very close one. Not only are thousands of specimens transferred to the National Herbarium by the Department each year, but the herbarium is used constantly by many members of the staff of the Bureau of Plant Industry and Bureau of the Biological Survey, and in many instances, extensive work of identification of material for these bureaus is performed by the staff of the National Herbarium. Until recently nearly all botanical material collected through the wide activities of the Bureau of Biological Survey was so determined, and at the present time all specimens collected in the national forests of New Mexico under the auspices of the Forest Service are referred here for identification. In 1912, the grass collection maintained by the Bureau of Plant Industry was transferred to the custody of the Smithsonian Institution, office and herbarium space being provided at the National Herbarium, of which the collections thus became an integral part. The staff, consisting of Dr. A. S. Hitchcock and Mrs. Agnes Chase with two assistants, is thus maintained by the Department of Agriculture. A large number of monographic and regional papers on grasses by Doctor Hitchcock and Mrs. Chase have been published in the Contributions from the U. S. National Herbarium, and the cooperation is in other ways particularly close.

This relationship is equally close in other divisions of the Department of Biology. Cooperation between the Division of Mammals and the Biological Survey began in 1889 and has continued actively in force to the present time. During this period (to December 31, 1922) the number of specimens of mammals alone brought to the Museum by the Survey has been 126,240, besides thousands of specimens of other classes. The mammal and bird material, by agreement made June 10, 1889, is kept separate from the Museum collection proper, and is reserved for the use of the Survey. For handling this collection the Museum has furnished services in cataloguing, cleaning, and numbering the specimens. The Survey has taken charge of the arrangement and general management of its collections, employing for this purpose a force which has averaged, during the past ten years, five persons.

The work of the Division of Insects and that of the Bureau of Entomology are so closely related that it is difficult at some points to draw a line of separation. The Museum affords office space to 14 specialists of the Bureau staff, and about 12 preparators, typists, indexers, etc. The primary function of these specialists is to determine material sent in by the field workers of the Bureau throughout the United States. This makes it necessary that they should have access to correctly named and extensive collections. Hence it has been arranged that each should have charge of the group in the Museum's collections in which he specializes.

Mississippi Pearl Fisheries.—In 1907 Dr. Paul Bartsch was detailed to the Bureau of Fisheries to undertake an investigation of the pearl fisheries of the Mississippi. This survey resulted in the accumulation of material which threw light upon the then existing distribution of the various species of fresh water pearly mussels, their abundance, and likewise their utilization. Information was also gathered pertaining to the output of fresh water pearls and the pearl button industry.

Research work on Shipworms.—In cooperation with the American Wood Preservers Association, Dr. Bartsch has been called upon in connection with various topics covering the shipworm, a pest which causes an annual loss of millions of dollars in American waters.

He has also been called upon to identify the material taken by the New York Committee on Marine Piling Investigations of the National Research Council in their reconnaissance work.

Experiments in heredity.—Since 1912 Dr. Bartsch has been engaged in a series of experiments in heredity under the joint auspices of the Smithsonian and Carnegie Institutions. Mollusks were collected at the Bahamas, Porto Rico, and Curacao and transplanted to the Florida Keys and the Tortugas. Many points of cross breeding have resulted.

Cooperation with the Chemical Warfare Service.—Through breeding experiments conducted by Dr. Bartsch upon local land mollusks during the years from 1899 to 1907 was made possible the demonstration of a method by which the garden slug could be used as a poison gas detector. Dr. Bartsch was detailed to the Chemical Warfare Service for a period of 11 days working upon this problem.

Other cooperation by the Division of Mollusks.—Dr. W. H. Dall reports cooperation with the Wagner Free Institute of Philadelphia in preparation of a report on the Florida Tertiary Collection; with the Bishop Museum of Honolulu on the Molluscan fauna of the Hawaiian and Palmyra Islands; with the Museum of Comparative Zoology on the Blake and Albatross dredgings and the Wild Duck collections; with the Department of State on the Alaskan Boundary (the conclusions of this report were exactly adopted in the subsequent arbitration); with the California Academy of Sciences in a study of the landshells and fossils of the Galapagos Islands; with the Peruvian government; the Brooklyn Institute, and the Harriman Alaska Expedition and with the U. S. Fish Commission in a study of the Molluscan fauna of Porto Rico.

DEPARTMENT OF GEOLOGY

Services as Expert on Structural Materials.—In 1881-1882 the Head Curator of Geology was detailed for work with the Tenth Census in connection with the building stone industry. This work involved the identification of several thousand specimens and the compilation of the matter relating thereto as finally published in the quarto volume relating to this industry. During the Twelfth Census he was again detailed for similar work, the results of which are to be found in the report on Mines and Quarries (1912). In 1913 he was detailed for services with the Lincoln Memorial Commission in inspection of the quarries at Yule Creek, Colorado, and of the material as delivered on the grounds in Washington. For like services he has not infrequently cooperated with the Engineer in charge of Public Buildings and Grounds; the Architect of the Capitol; and the supervising architect of the Treasury; and with associations and committees in charge of large structures. Among these may be mentioned the St. Albans Cathedral in Washington; the new City Hall in New York City; the New National Museum; the City Post Office, and other post office buildings; the State Library at Hartford, Conn.; and the columns on the east front of the Treasury building.

Resurvey of the petrified forests.—During the season of 1911, the Head Curator was detailed, at the request of the Commissioner of Public Lands to make a resurvey of the territory included in the Petrified Forest National Monument with a view of reducing its limits so far as practicable. The work was accomplished under the joint auspices of the Smithsonian Institution and the Land Office, assisted by an outfit furnished by the Santa Fe Railroad, whose property was in part involved. The resurvey resulted in a reduction of the total area of 40½ square miles without detriment, and the turning back of the remainder to the original owners.

Petrographical work in Montana.—During the field seasons of 1907 and 1908, Dr. Merrill, at the request of Dr. A. C. Peale of the U. S. Geological Survey, was detailed to accompany him into the field for the purpose of identifying and otherwise studying the eruptive rocks within the area known as the Three Forks Sheet, all expenses aside from salary being borne by the Survey.

Studies of the so-called Meteor Crater of Arizona.—During the summer of 1907, the Head Curator was detailed in accordance with an invitation from the Standard Iron Company of Philadelphia to make studies of the remarkable crater form depression near Canyon Diablo. The expenses on the ground were paid by the Iron Company, and all the necessary facilities and materials furnished. The results were published in the Smithsonian Miscellaneous Collections, vol. 50, 1908.

Mineralogical Services during the late War.—In the course of experimental work being carried on by the Navy, particularly along lines involving the piezo electric properties of minerals, there early arose an emphatic demand for the mineral quartz in sizes and qualities not then obtainable from dealers. The collections of the department of Geology were practically drained of such minerals in the furtherance of this and other experimental work, and the Head Curator was therefore detailed to secure a sufficient supply of the needed material, not only for the U. S. Government, but for Great Britain and France as well. The search was actively and successfully carried on until the close of the war.

Cambrian and Ordovician Paleontology and Stratigraphy of Virginia.—The study of the great Cambro-Ordovician limestone series of the Appalachian Valley, long mapped as a single formation, was undertaken by Dr. R. S. Bassler in 1905 in cooperation with the Virginia Geological Survey, with the intention of discriminating the stratigraphic units thought to be present in this hitherto undivided series. After several seasons of close mapping and collecting of fossils, a new geologic map of Virginia west of the Blue Ridge, and a volume of 309 pages, fully illustrated, were published by the State.

Cooperation with the Geological Survey of Maryland.—Cooperative work with this organization has been actively carried on since 1901, Dr. Bassler alone, or in collaboration with Dr. E. O. Ulrich, having prepared a number of reports on the paleontology and stratigraphy of the state. The results of their work have been published in six of the reports issued by the Survey. The expenses of the work were borne by the State, and the types of the described fossils became the property of the National Museum.

Geologic studies in Central Tennessee.—Cooperation with the State Survey of Tennessee has resulted in two seasons of field work on the part of Dr. R. S. Bassler in working out the stratigraphy of a critical area—the Franklin quadrangle of 250 square miles just south of Nashville. The results of this work will be published by the State Survey.

Cambrian Paleontology of Wisconsin.—Active work on the Cambrian faunas of Wisconsin in cooperation with the State Geological Survey is now being carried on by Dr. C. E. Resser with the help and advice of Secretary Walcott and Dr. E. O. Ulrich, both of whom have made extensive collections in that state. The results of Dr. Resser's work will be published by the State Survey, but the type specimens will remain in the National Museum.

Permian Paleontology of the Island of Timor.—In cooperation with the Dutch government, Dr. Bassler has undertaken the study of the fossil Bryozoa of the Island of Timor.

Studies in Recent and Cenozoic Bryozoa.—By cooperation with the Bureau of Fisheries, the Carnegie Institution of Washington, and other organizations, Dr. Bassler, in collaboration with the leading bryozoologist of Europe, Ferdinand Canu, has engaged in extensive studies on the Recent Bryozoa of the Philippine Islands; the Tertiary Bryozoa of North America; and the Cenozoic Bryozoa of the West Indies and Central America.

Cooperation with the Geological Survey of Canada.—Since 1910 Secretary Walcott has been in cooperation with the Canadian Survey in the study of the pre-Devonian stratigraphy and faunas of the Rocky Mountains.

The classic Silurian area, the Island of Anticosti, was made the subject of detailed geological and paleontological surveys by the Canadian Geological Survey, in cooperation with various specialists. To Dr. R. S. Bassler was assigned the study of the large collections of Bryozoa and Ostracoda, the results to be published by the Canadian Government, but the type specimens to remain in the National Museum.

At the request of the Canadian Survey, Mr. C. W. Gilmore was detailed for a period of two months for the purpose of studying and describing dinosaurian remains in the collections of the Survey at Ottawa.

Vertebrate Studies with the National Park Service.—At the request of the National Park Service, Mr. Gilmore was detailed to conduct a paleontological survey of an area temporarily withdrawn from settlement and known as the "Mastodon National Monument," in north central New Mexico. As a result of this investigation and unfavorable report, the area was returned to the public domain.

Studies of North Carolina Vertebrate Fossils.—On the invitation of the State Geologist of North Carolina, Mr. Gilmore prepared a report on the Extinct Reptilia of the state, to be a part of a forthcoming publication on the geology and extinct life of North Carolina.

Vertebrate Studies at the University of Alberta, Canada.—For two months during the year 1922, Mr. Gilmore was released from his duties at the National Museum to assist in the arrangement and installation of the fossil specimens in the museum of the University of Alberta, and to describe the dinosaurian remains.

Cooperation with the U. S. Geological Survey.—Cooperative work between the Department of Geology and the U. S. Geological Survey is so constant, and the relationship so close, that specific instances are difficult to enumerate. About one-half of the space allotted to the department is occupied by members of the Survey staff whose work requires access to the classified collections, utilized as office rooms and for storage of their materials, paleobotanical library, etc. Since the Survey has on its staff no research workers in vertebrate paleontology, all of their collections of this nature must be sent here for identification, and members of our staff have been detailed to accompany their field parties in order to identify vertebrate remains and thus assist in the proper determination of formations. In this connection mention may be made of trips by Mr. Gilmore with Messrs. Lee and Stanton in northeastern New Mexico, in 1909; with Mr. Lloyd in the Judith Basin, Montana, in 1917; and to northeastern

Montana in 1913 to investigate the reported occurrence of vertebrate fossils in the Two Medicine formation, which work resulted in the acquisition of a good collection and the establishment of the first vertebrate faunal list of that formation. Extensive collections made by Survey parties in the San Juan Basin, New Mexico, in 1914-1915, were studied and described by Mr. Gilmore, thus establishing definite vertebrate faunas for the Ojo Alamo, Kirtland, and Fruitland formations. In 1921, Mr. Gidley, in cooperation with the Survey, made extensive collections in the San Pedro Valley, Arizona, thus settling certain involved questions of stratigraphy regarding the late Tertiary and early Pleistocene deposits on which the Survey had been working for a number of years. In all of the studies mentioned, the preparation of the material is done in the Museum laboratory.

Dr. R. S. Bassler has also cooperated with the Survey in mapping quadrangles in areas where his special knowledge of the rocks has made this work advisable; the Head Curator visited Florida in 1905 to investigate economic resources for the Survey, and Messrs. Foshag and Shannon of the divisions of mineralogy and economic geology are almost constantly in cooperation with this organization in determinative and descriptive work.

DEPARTMENT OF ANTHROPOLOGY

Archeological Investigations in Guatemala.—In 1914, Mr. Neil M. Judd was asked to participate in archeological investigations at Quirigua, Guatemala, conducted under the direction of Dr. Edgar L. Hewett. One of the objects of the expedition was the reproduction in plaster of several of the huge stone monuments at Quirigua. This work was assigned to Mr. Judd, who, with his assistants, completed casts from six of the colossal stelae by the use of glue molds, a material never before employed for this purpose in the torrid zone.

Archeological Investigations in New Mexico.—An important exploration was begun by the National Geographic Society in cooperation with the Museum. The Society appropriates $75,000 for five years' work in the ancient ruin of Pueblo Bonito, Chaco Canyon, New Mexico, under the direction of Mr. Judd, the specimens secured becoming the property of the Museum. This is the largest scheme of cooperative work ever engaged in by the Department, and is looked upon as opening up great possibilities for further exploitation by the National Geographic Society.

Anthropological Studies at the Panama-California Exposition.—By arrangement between the Institution and the Panama-California Exposition, Dr. Hrdlička of the division of Physical Anthropology was given charge of the preparation of the anthropological exhibit. This important cooperation necessitated explorations in Alaska, the United States, Peru, British Guiana, South Africa, Siberia, and other countries, for procuring physical and ethnological material, the latter being shared with the National Museum. As a feature of this cooperation, there was prepared in Washington a collection illustrative of the science of Physical Anthropology, which is now shown in the San Diego Museum under the direction of the School of American Archeology.

Anthropological work with the Rockefeller Foundation.—Under the auspices of the Rockefeller Foundation and the Peking Medical College, Dr. Hrdlička visited several countries of the Far East during 1920. During this trip he continued studies on the origin of the American aborigines, examination of the oldest skeletal and other human remains in Japan, furthered the interests of medical and physical anthropology in China, and made a visit to the rapidly disappearing full blooded Hawaiians. Dr. Hrdlička assisted in the development of medico-anthropological work at the Union Medical College and the organization of the Anatomical and Anthropological Association of China.

Work with the Department of Justice.—In the spring of 1916, Dr. Hrdlička cooperated with the Departments of Justice and Interior in investigations in which the rights of Indian lands were involved. Some three months were consumed in the work and large areas of land restored to their original ownership.

DEPARTMENT OF ARTS AND INDUSTRIES

This department cooperates with other Government bureaus, with educational establishments, with publishers and authors, and with trade associations and industrial enterprises.

The *Divisions of Mineral and Mechanical Technology* are concerned with the interpretation of the efforts of the engineering professions in applying the results of scientific research to industry. To conduct the work, the most logical means is cooperation with industrial enterprises for the technologic aspects, and with Federal statistical bureaus for the economic aspects. Since the inception of the division, cooperation has been carried on with many firms engaged in the exploitation of mineral resources, as well as those engaged in more specialized industrial operations. As an example of educational work mention may be made of cooperation with the Pennsylvania Department of Education and Mr. Samuel S. Wyer, of Columbus, Ohio, in the preparation of a book on the natural resources of Pennsylvania, prepared expressly for and presented to the seventh and eighth grade geography teachers of the state. The book is an application of the Museum's methods to a single state, and, as far as possible, the data are derived from the Museum's exhibits.

The *Division of Textiles* presents another phase of the important resources and industries of the United States. The collections, by their accurately recorded data, have served individual firms for settlement of patent litigation; have been used to illustrate the arguments of trade associations before the Ways and Means Committee in Congress; and are at all times available as reference materials for the use of the Tariff Commission or others presenting technical questions to legislative bodies. The division acts in cooperation with other Government bureaus in doing for them certain propaganda work in bringing their aims before the public by means of specially prepared exhibits; in preserving for them valuable historical materials which must be often consulted and in which the public has an interest; and in the identification of commercial raw materials. It cooperates with trade associations, corporations, and individuals in the presentation of exhibits illustrating the industries of the United States.

The *Division of Medicine* cooperates with all agencies by the visual presentation of the most recent advances in sanitary science and the health of man; with the National Medical Associations in the development and presentation of educational exhibits illustrating the history of medicine and pharmacy in America, and the part played therein by different schools of thought and practice; and with the War Department in the identification of narcotic drugs.

The *Division of Graphic Arts* cooperates mostly with manufacturers and others to increase and perfect educational exhibits in which the technical as well as the artistic side of the various processes and trades known as the graphic arts are displayed.

Bureau of American Ethnology

Other branches of the Government, the U. S. Supreme Court, both branches of Congress, educational and scientific institutions, and hundreds of individuals all over the world, have called on this Bureau for ethnological information. Its library is used constantly for study and consultation by students; exhibits have been prepared for various expositions; and the following detailed list covers some of its cooperative undertakings.

National Park Service.—Excavation and repair of the prehistoric ruins on the Mesa Verde National Park, Colorado.

University of Texas.—Study and excavation of antiquities in Texas.

Davenport Academy of Sciences.—Excavating prehistoric mounds near Fairport, Iowa, and making ethnological collections among the Fox Indians for that institution.

American Museum of Natural History.—Conducting ethnological researches among the Tlingit and Haida Indians of Alaska.

Columbia University.—Collecting material from the west coast of North America, and publication of results.

Museum of the American Indian (Heye Foundation).—Study of West Indian collection at that museum and field work in the Antilles. Work at Hawikuh and Nacoochee.

Illinois State Historical Society.—Investigating the Peoria-Miami Indians.

School of American Research, Santa Fe, N. M.—Studies in ethnogeography, ethnozoology, and ethnobotany.

Department of Justice.—Detail of a member of the staff to translate Spanish documents bearing on Indian land claims at the Tejon Ranch, California.

Agricultural Department.—Identification of plants to which certain Indian names are given.

Board of Geographic Names.—Services of chief as a member of this Board in collaboration with many other departments of the Government.

Studies of the Haida Indians of British Columbia and Alaska.—An expedition to study the Haida Indians, financed jointly by the Jesup North Pacific Expedition and the Bureau.

It is felt that the above work stimulates public interest in the various industries of the American aborigines, and by the preservation of the ruins of their former habitations, gives impetus to the movement called " See America First." The Bureau is frequently called upon by business companies for translation of Indian names, and for pictures, etc., for commercial use. It also aids Camp Fire Girls, Scouts, etc.

The National Gallery of Art

The National Gallery of Art is now in the third year of its existence as a separate unit of the Smithsonian Institution, and energies of the limited staff have been devoted mainly to the care, cataloguing, labeling, and installation of the collections. Cooperation with other galleries and other institutions interested in art has been carried out as opportunity offered:

(1) By correspondence devoted to art subjects.

(2) By exchange of photographs of art works.

(3) By contributing matter relating to the collections for publication.

(4) By publication of illustrated catalogues of the collections.

(5) By lectures on the collections delivered in educational centers throughout the country.

(6) By the temporary loan of art works for exhibition.

(7) By circulating exhibits shown in art centers throughout the country.

(8) By permitting the copying of art works; by permitting teachers to instruct their classes in the Gallery; and by permitting portrait painters to hold their sittings in Gallery rooms.

(9) By exhibiting art works belonging to artists and collectors seeking public attention, and by the care and display of collections belonging to other galleries during periods of repair or construction of buildings.

National Zoological Park

The National Zoological Park is constantly cooperating with other government departments and with non-government scientific establishments throughout the world. The following specific instances of such cooperation are typical of its service to other institutions:

(1) Cooperates with the Biological Survey in establishing breeding experiments.

(2) Furnishes animals to the Bureau of Animal Industry and the Public Health Service for pathological investigations.

(3) Has at numerous times aided the Bureau of Engraving and Printing in obtaining portraits of animals for use on notes, bonds, etc.

(4) Has furnished large quantities of fertilizer, etc., to the office of Public Buildings and Grounds.

(5) Furnished needed materials for experimental work to the Bureau of Standards.

(6) Furnished birds, etc., and cared for birds and reptiles belonging to the Pan-American Union.

(7) Furnishes anatomical material to educational and scientific institutions throughout the country.

(8) Through members of Congress, and otherwise, furnishes information to public institutions in various parts of the United States,

especially plans for construction of buildings, cages, enclosures, care of wild animals, etc., and cooperates constantly with zoological societies and similar public and private organizations in various activities.

The Astrophysical Observatory

The present work of the Astrophysical Observatory is of special interest to meteorologists, for since the temperature and other weather conditions of the earth depend upon the sun, the variations of the sun may probably produce predictable changes in weather conditions.

For several years past, the monthly records of solar radiation have been furnished to the United States Weather Bureau for publication in its Monthly Weather Review. Since December, 1919, telegraphic reports of the daily observations at the Chile observing station have been sent to the Weather Service of Argentina, and have been employed there for forecasting purposes. The Argentine Government, at present, publishes weekly a forecast, one week in advance, based upon the Chilean observations of the Smithsonian Institution.

Frequent requests for information in regard to matters of solar radiation, physics, and astronomy are answered by the Astrophysical Observatory. (See also under Hodgkins Fund, p. 8.)

International Exchanges

Perhaps the most far-reaching of the forms of cooperation in which the Smithsonian has taken a leading part is that universally known under the title of the Smithsonian International Exchange Service.

This system was established early in the history of the Institution, at first purely as a channel for the interchange of scientific publications and specimens, and therefore as a direct means for "the diffusion of knowledge," a means which has proved to be a great benefit to the scientific institutions of the world, and incidentally to Congress, in building up the unequaled collection of works of reference deposited in its library.

In order to convey an idea of the present magnitude and character of the exchange transactions, it may be stated that during the year 1889, 17,218 packages were mailed to correspondents in the United States, and 693 boxes, containing 58,035 packages, were shipped to agents abroad for distribution to correspondents in nearly every civilized nation of the earth. The total number of packages received was 75,966, of which 34,996, or nearly one-half, were governmental exchanges. In 1922, the number of packages handled had increased to 383,157, weighing 592,600 pounds. The following table will show the consignments for foreign countries during the year 1921-22.

CONSIGNMENTS OF EXCHANGES FOR FOREIGN COUNTRIES

Country	No. of boxes	Country	No. of boxes
Argentina	119	Italy	121
Austria	203	Jamaica	3
Belgium	89	Japan	80
Bolivia	3	Latvia	12
Brazil	49	Netherlands	80
British Colonies	15	New South Wales	43
British Guiana	1	New Zealand	28
Bulgaria	9	Nicaragua	2
Canada	30	Norway	47
Chile	36	Paraguay	4
China	164	Peru	22
Chosen	1	Poland	49
Colombia	26	Portugal	22
Costa Rica	18	Queensland	17
Cuba	5	Rumania	32
Czechoslovakia	128	Salvador	4
Danzig	5	Siam	2
Denmark	41	South Australia	25
Ecuador	16	Spain	48
Egypt	11	Sweden	86
Esthonia	11	Switzerland	91
Far Eastern Republic	2	Syria	4
Finland	20	Tasmania	12
France	201	Ukrainia	2
Germany	523	Union of South Africa	30
Gt. Britain & Ireland	364	Uruguay	23
Greece	17	Venezuela	14
Guatemala	3	Victoria	50
Haiti	6	Western Australia	14
Honduras	2	Yugoslavia	69
Hungary	54		
India	7	Total	3,215

THE INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE

Still another form of cooperation which is widespread in its numerous ramifications is found in the International Catalogue of Scientific Literature, which, dating from 1901, is an outgrowth of *Catalogue of Scientific Papers* published by the Royal Society of London. The prime initiative in this work may be ascribed to Professor Henry, who, at the Glasgow meeting of the British Association in 1855 brought the matter up for consideration. A full history of the movement is said to be contained in the first volume of this catalogue issued in 1867 by the Royal Society. The possibility of preparing a complete index of scientific literature by international cooperation was first taken into consideration by the Royal Society about 1893. An international conference for considering the matter was held in London in 1896, at which there were present delegates from Canada, Cape Colony, Denmark, France, Germany, Greece, Hungary, India, Italy, Japan, Mexico, Natal, the Netherlands, New South Wales, New Zealand, Norway, Queensland, Sweden, Switzerland, the United Kingdom, and the United States. It is not necessary to go into the details of the final arrangement other than to say a "Regional Bureau" was established under the auspices of the Institution, entrusted with the duty of indexing and classifying titles of all scientific papers published in the United States, the same to form a part of the International Catalogue issued by the central bureau in London.

V. CONCLUSION

It is impossible to estimate either the value or cost of the numerous and varied forms of cooperation mentioned above. The work has become largely a matter of routine and cannot be considered independently of other duties, often carried on at the same time. *"The most important service by far which the Smithsonian Institution has rendered to the nation from year to year since 1846—intangible, but none the less appreciable—has been its constant cooperation with the Government, public institutions, and individuals in every enterprise, scientific or educational, which needed advice, support, or aid from its resources."* This statement by Dr. G. Brown Goode[1] is felt to be fully borne out by the foregoing pages. While much has been omitted that might properly have found place among the enterprises here recorded, it is thought that sufficient instances have been given to show the character and wide scope of the work. A list of institutions or names of private individuals with whom the Institution has cooperated would run into the thousands, and their publication serve no useful purpose. Suffice it to say that the Institution's cooperative activities are continuous and world-wide in distribution.

GEO. P. MERRILL, *Chairman,*
Committee on Cooperation.

May 16, 1923.

[1] Rep. Smithsonian Institution, 1897, Pt. 2, pp. 320-321.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 76, NUMBER 5

THE TELESCOPING OF THE CETACEAN SKULL

(WITH EIGHT PLATES)

BY
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(PUBLICATION 2720)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
AUGUST 31, 1923

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

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(With 8 Plates)

CONTENTS

SIGNIFICANCE OF THE WORD "TELESCOPING"

The skeleton of the cetaceans shows more conspicuously than that of any other group of mammals the simultaneous action of two opposite trends of modification: the first toward reduction and elimination of those parts which have been rendered useless by a change from an original mode of life to another of a very different kind, the second toward the extreme remodeling of the parts which remain actively functional under such new conditions. The changes of the second type are those which present the greatest interest. Among them the most important are shown by the skull.

In mammals whose skulls have departed widely from the generalized original form the modifications have usually been made through great changes in the shape or size of individual bones with comparatively little alteration in the mutual contact-relationships of the parts concerned in the process. In the rare instances when such changes of contact-relationship occur, as the extension of the premaxillary backward over the frontal above the orbit in the elephants, or the covering of the parietals by the forward advancing occipital shield in the burrowing rodents of the genus *Spalax,* the changes are recognizable as exceptions to the general course of modification which the skull is undergoing. By the more usual process have been produced such specialized types of skull as are seen in elephant, seacow, brontothere, anteater and man. In striking contrast to this kind of remodeling, the process which the skulls of all known cetaceans except the zeuglodonts have undergone is a highly developed system of "telescoping"; that is, the portion of the skull lying behind the rostrum has been shortened, not so much by a reduction of the anteroposterior diameter of individual bones (except the parietal), as by a slipping of one bone over another or by the interdigitating of some of the elements. Alteration of contact-relationship is here not the exception but the rule. In this manner unusual conditions have arisen; such as contact of the premaxillary and supraoccipital (pl. 7, fig. 3; pl. 8, fig. 7), the presence at one transverse plane of parts of the nasal, premaxillary, maxillary, parietal, and frontal (pl. 8, figs. 6, 7), the partial covering of the supraorbital process by the lacrimal (pl. 5, fig. 6), the entire covering of the palatine and alisphenoid by the pterygoid (p. 31) or the presence at one perpendicular plane of parts of the occipital, frontal and nasal (pl. 8, fig. 9). These rearrangements of the elements of the skull are not in any general sense mere degenerative changes. They affect the skull's fundamental structure, and they are peculiar to cetaceans. With little doubt, therefore, they represent responses to stimuli which are in some way directly connected with the conditions under which these animals live—perhaps most particularly with the habit of rapid, fish-like, pelagic swimming; in other words they are active adaptations in one of the parts of the skeleton most essential to cetacean existence. Hence the varying degree of their perfection may properly be regarded as indicating the varying extent to which different cetaceans have departed from the original land mammal type. While the fact of telescoping in cetacean skulls has long been known, the details of the process throughout the group have never to my knowledge been studied, nor does any one appear to have attempted to show what phylogenetic importance these details may present.

Considered purely from this point of view the cetacea are divisible into two groups: those in which telescoping is entirely absent and those in which it is conspicuously developed. There are no known intermediate stages between these two conditions. All of the zeuglodonts belong in the first group. All of the other cetaceans whose skulls have been described belong in the second. As the zeuglodonts are not known to have existed since early Tertiary times, the members of the second group, abundantly represented in the seas of to-day, may be alluded to collectively, whether living or fossil, as modern cetacea.

GENERAL CONDITIONS IN ZEUGLODONTS

Concerning the zeuglodonts there is little to say. All of the published figures as well as the rather scanty material which I have been able to examine agree in indicating that the bones of the skull retain their original relationships (pl. 5, fig. 1). Highly specialized on this primitive ground plan, and in a direction toward elongation and narrowing of the post-rostral portion, the zeuglodont skull, in its general structure, appears to be removed from rather than antecedent to the line of development which led to the telescoped, broadened condition of the post-rostral region seen in the skulls of all modern cetacea. It seems not improbable that the zeuglodonts were for the most part animals with relatively long bodies and small heads as compared with the living whales and porpoises [1] and that the culminating point in their characteristic line of development is indicated by *Basilosaurus,* the genus in which these tendencies appear to have been carried to the greatest extreme. The superficial resemblance which the zeuglodonts bear to reptiles as a result of these peculiarities has often been noticed; and it should be observed in the present connection, that, like the zeuglodonts, the extinct marine reptiles seem to have been without any tendency toward cranial telescoping. It may not be impossible that in both instances the relatively small head was not subjected to the mechanical forces needed to call forth the peculiar reaction which has been the dominant factor in the development of the skull in modern cetaceans (see pp. 38-39). A further reason for regarding the known zeuglodonts as probably not directly ancestral to any of the recent whales is the circumstance that in spite of the extreme degree and peculiar character of the general specialization attained by some members of the zeuglodont group the dentition of these animals appears to have been, even in such an aberrant type as *Basilosaurus,* uniformly undergoing a simple and not very unusual process of reduction in the normal mammalian manner, a tendency which would not lead by any known process to the remarkable and unique condition of polyodonty through which the modern cetacea have either once passed or are now in.[2] While it appears to me

[1] The proportion of head length to total length in *Basilosaurus* is about as 1 to 12. It is not sufficiently known in other members of the group. In living whales it is usually somewhere near 1 to 6 (less in *Kogia* and more—even as high as 1 to 2½—in the balænids).

[2] The two principal explanations of the origin of this polyodonty—intercalation of milk teeth among the teeth of the permanent dentition, and the splitting up of serrate permanent teeth into numerous simple elements—are purely hypothetical, resting on no processes actually observed. See Winge, Smithsonian Misc. Coll., Vol. 72, No. 8, pp. 50-56, July 30, 1921.

doubtful that the known zeuglodonts were ancestral to any of the recent whales it seems probable that they came from a terrestrial stock which was nearly related to the latter's forerunners; and there can be little question that in certain details of structure they possess features which are morphologically intermediate between those of early land mammals and those of some living cetaceans. These features will be dealt with in discussing the probable course of development of the modern whales (pp. 11-12).

GENERAL CONDITIONS IN MODERN CETACEA; SUGGESTIONS AS TO THE POSSIBLE MECHANICAL ORIGIN OF THESE CONDITIONS

Concerning the modern cetacea the most conspicuous facts are these: (a) That the telescoping of the skull was far advanced in the earliest known extinct genera, and (b) that this process has developed according to two different plans. No transitional stages between these two plans of development are known; and no fossil cetacean has yet been described in which the skull has been definitely shown to be so constructed as to furnish the elements needed for the development of both. While there are important variations in details, the fundamental schemes of the two plans or types are as follows. In one type (pl. 1, figs. 1*a,* 1*b*) the entire proximal portion of the maxillary (*a. pr.*) passes up over the frontal and backward to approach or meet the supraoccipital at a level behind the orbit (*orb.*); laterally it spreads out over the expanded supraorbital wing of the frontal. Backward motion of anterior elements is the most obvious feature of this first process. In the other type (pl. 1, figs. 2*a,* 2*b*) the broad outer part of the hinder maxillary border (*o. pl.*) projects obliquely downward and backward under the anterior margin of the great supraorbital wing of the frontal, while the narrow inner part (*a. pr.*) fits closely into the body of the frontal on the upper surface of the forehead; the upper surface of the expanded supraorbital wing of the frontal is thus left bare. As though further backward progress of the maxillary were rendered difficult by this double interlocking of maxillary and frontal, telescoping is chiefly accomplished by forward extension of the occipital and parietal to and beyond the median orbital level (*orb.*). Forward motion of posterior elements is the most obvious feature of this second process. The first plan is peculiar to the dolphins and toothed whales, the second is confined to the baleen whales.

The opposite trends of motion in the elements chiefly concerned with the telescoping process according to the two plans are especially well shown by figures 2 (*Platanista*) and 3 (*Balænoptera*) of plate 6. Here it will at once be seen that in the toothed cetacean the long axes of the frontal, parietal and squamous portion of the squamosal slope upward and backward as though forced into this position by some backward-crushing power acting through the elongated ascending process of the maxillary. In the baleen whale, on the contrary, these axes all slope upward and forward as though they had been dominated by a foreward-crushing power acting through the elongated occipital shield. The horizontal position of the same axes in a normal skull, where no elongation of the maxillary or the occipital has taken place, is shown in figure 1 of plate 7.

The skull of a finback whale is thus seen to be telescoped in a manner so unlike that of a dolphin that it is at first difficult to understand how two such opposite types could have originated. The fossils thus far described give no clue to the probable history of the two processes of telescoping. Such extinct genera as *Cetotherium, Archæodelphis,* and *Agorophius* show conditions less advanced than those found in living forms; but no extinct cetacean has yet been made known in which there is certainly a confusing or blending of the two types, or in which there has been demonstrated the presence of a structure from which both plans could be elaborated.

A clear understanding of some of the more important mechanical features of the two types can be gained by examining the different ways in which contact between the bones concerned in the telescoping process is established in other mammals. Without attempting to work the subject out in detail I have found that in mammals which have a broad area of contact between the maxillary and frontal above the anterior part of the orbital rim two kinds of relationship can be seen: (a) The maxillary may slide over the frontal in the form of a thin plate or tongue of bone (fox, pl. 2, fig. 1, *a. pr.*), or (b) the edges of the bones may be solidly locked by interdigitating processes (bear) or by slipping the edge of the maxillary obliquely downward into the substance of the frontal (furseal, sea-lion, pl. 2, fig. 2, *a. pr.*). Sometimes the two methods are combined so that the maxillary extends freely up over the frontal alongside of the nasal but sends a well developed flange downward into the frontal at the edge of the orbit (cat, some mustelines). Turning to the line of contact between the occipital and parietal it is again seen that various kinds of juncture occur: the bones may come solidly together (bear, raccoon), or either may slightly override the other (parietal over occipital in fox, pl. 2, fig. 1, and domestic cat, occipital over parietal in furseal and sea-lion, pl. 2, fig. 2). It is not now essential to try to explain the significance of these various forms of interlocking in mammals whose skulls are not telescoped. The important point is to recognize that among such mammals are found some primary structural elements from which it would appear to be mechanically possible to initiate both of the processes that have been elaborated in the skulls of the modern whales. In the fox (pl. 2, fig. 1) may be observed the combination of peculiarities which, so far as they go, are the ones seemingly needed to lead to the toothed whale type. Anteriorly the broad ascending process of the maxillary (*a. pr.*) overrides the margin of the frontal in a direction which, if continued, would carry it freely back over the base of the postorbital process and beyond to the highest point of the braincase. At the back of the skull the occipital fits so solidly against the bones in front of it that any forward progression of the upper part of the occiput would apparently need to be accomplished by eating into the substance of the hinder portion of the parietals, a process which can easily be imagined to present greater mechanical difficulty than the unobstructed backward sliding of the maxillaries over the upper surface of the frontals. The final approximation or contact of occipital and maxillary might therefore be expected to take place at a level decidedly behind the orbit, exactly as happens in the great majority of toothed cetacea (see especially pl. 1, fig. 1*a*; pl. 5, fig. 5; pl. 7, figs. 2, 4). In the furseal and northern sea-lion (pl. 2, fig. 2), on the other hand, a combination occurs which would seem to furnish a structural beginning that might lead equally well toward telescoping according to the other plan. Here the maxillary (*a. pr.*) is so firmly locked with the frontal as to have the appearance of opposing a serious check to backward movement, while the occipital overlaps the parietal as freely as the maxillary overlaps the frontal in the fox. Thus the mechanical elements are provided which might finally lead to the forward extension of the occipital shield to the level in front of the orbit which it reaches in the baleen whales. No series of ancestral or of less specialized living forms is known in which the skulls show stages intermediate between the conditions seen in the brain case of the sea-lion and the baleen whales, but a nearly parallel morphological series can be observed leading from the large occipital shield which conspicuously overrides the parietals in *Spalax* (pl. 8, fig. 8) back through such cricetine rodents as *Myospalax* and the more fossorial species of *Arvicola* to a completely unmodified occipital region like that of *Neotoma*. Longitudinal sections of the skulls of these rodents show that the overlapping of the posterior elements is strictly of the sea-lion type, and that the specialized structure of *Spalax* is based on the working out of a condition latent in allied rodents whose skulls have remained normal.

While the obvious superficial characters of the two methods of telescoping as just described are easily observed in adult cetacean skulls, the more essential underlying features of the processes can only be studied in specimens young enough to permit of disarticulation.[1] When such material is examined it becomes evident that the key to an understanding of the differences is probably to be found in the structure of the posterior portion of the maxillary, the region whose morphology appears to be more fundamentally essential in this connection than that of any other part of the skull. In the baleen whales the orbital portion of the body of the maxillary[2] is present and well developed as a large "horizontal ventral" plate projecting conspicuously behind and beneath the infraorbital foramen. The jugal comes in contact with the postero-external portion of this plate, at a level below, behind and considerably lateral to the foramen (pl. 1, fig. *2b;* pl. 3, fig. 3; pl. 4, fig. 3). In the toothed cetacea (pl. 1, fig. 1*b;* pl. 3, figs. 5 and 6; pl. 4, fig. 2) the horizontal orbital portion of the maxillary is absent, and the jugal is interlocked with the maxillary at a point close to the infraorbital foramen and usually in front of it; always at a level very different from that at which contact is established in the baleen whales. It is therefore evident that the difference between the two kinds of relationship of the maxillary to the frontal in the modern cetacea is much greater and more significant than is implied by the usual idea that in the toothed whales the maxillary passes backward over the frontal while in the baleen whales it passes backward mostly under the frontal. For the large and conspicuous part of the maxillary which passes under the frontal in the latter group is a structure which the toothed cetacea do not possess (compare especially pl. 1, figs. 1*b* and *2b;* pl. 3, figs. 3 and 6; pl. 4, figs. 2 and 3). On the other hand the part of the maxillary which is common to the two groups, the ascending process, has in reality a homologous relationship to other structures in both types; the essential part of the great apparent difference is merely that in

[1] I have at my disposal young representatives of the genera *Balænoptera, Berardius, Delphinapterus, Delphinus, Globicephala, Grampus, Kogia, Lagenorhynchus, Physeter.*

[2] In normal mammals this part of the maxillary forms the floor of the anterior region of the orbit (see Jayne, Mammalian Anatomy, pt. 1, fig. 266).

the toothed whales the process (pl. 1, fig. 1*a, a. pr.*) is widely spread over almost the entire surface of the frontal including the outwardly expanded orbital wing, while in the baleen whales it is narrowly interlocked with the body of the frontal close to the nasal, leaving the orbital wing uncovered (pl. 1, fig. 2*a, a. pr.*).

At the same time that it has been telescoped the modern cetacean skull has been subjected to a process of widening, flattening, and basining in the frontal and basirostral regions. There appears to be little if any indication of this flattening or basining among the zeuglodonts. In most of the modern cetacea it is a noticeable feature of the skull (see particularly pl. 5, fig. 5; pl. 6, fig. 1; pl. 7, fig. 3). As the basining centers about the region of the base of the maxillary its details and results may have been modified by the two types of structure that have just been described. In the baleen whales the horizontally expanded supraorbital process or wing of the frontal seems to have been forced down from the normal mammalian position of the process seen in a sea-lion (pl. 2, fig. 2) or a zeuglodont (pl. 5, fig. 1) until its anterior half has come to lie against the similarly expanded orbital portion or "horizontal ventral" plate of the maxillary (pl. 1, fig. 2; pl. 6, fig. 3). The anterior part of the original orbital cavity is thus obliterated (compare pl. 1, fig. 2*b* with pl. 1, fig. 1*b*). The two bones are essentially in contact over a wide surface, but there is no semblance of fusion or interlocking between them, nor does their very unusual relationship appear to add anything to the strength or efficiency of the skull. On the contrary this broad approximating of the two expanded plates is to me more suggestive of a fortuitous and structurally unharmonious adjustment of these particular parts to that general necessity for widening and flattening of the basirostral region which the skulls of all the modern cetacea seem to be subject to. This appearance of mechanical weakness arises primarily from the excessive contrast between the very large orbital plate and the relatively minute ascending process by which alone the huge maxillary bone is directly fastened to the frontal (see pl. 1, fig. 2*a;* pl. 3, fig. 3; pl. 4, fig. 3); it is heightened by the thinness of the plate, the irregularity of its free margin (pl. 1, fig. 2*b*), and by the frequent presence of vacuities in its substance, features which strongly suggest an advanced stage of degeneration. In the toothed cetacea, however, the entire structure of this part of the maxillary has an aspect of mechanical efficiency and of perfect adjustment to free depressing and basining. The enlarged ascending process, widely expanded both backward and laterally (pl. 1, fig. 1*a;*

pl. 3, figs. 5, 6), provides adequate support for the rostral portion of the maxillary. Its superficial area in a skull of *Delphinus* (pl. 5, fig. 4) is about equal to that of the rest of the bone, in one of *Grampus* it is about twice as great; while in a pike whale it is less than one-twelfth.[1] There is, furthermore, no orbital portion of the bone to interfere with lowering the expanded postorbital process of the frontal to any required level. Basining, therefore, as might be expected, is, in this group, carried to the extreme, culminating in the conditions seen in the sperm whale (pl. 6, fig. 1) and *Kogia* (pl. 7, fig. 3).

In order to explain the origin of the two kinds of telescoping it appears to be necessary to look for some other factor than the work of different forces applied to the remodeling of one original type of structure (see pp. 35-39). Special elements of a kind which seemingly might have an important bearing on the initiation of two such processes in the superficial portion of the skull have already been shown (pp. 5-6) to exist among mammals that have not undergone cetacean modification. The skull of the fox and sea-lion respectively, furnish combinations resembling those which might be supposed to be required (pl. 2). Turning to the base of the disarticulated maxillary in the same two animals it immediately becomes obvious that here once more are apparently the looked-for conditions. The maxillary of a sea-lion (pl. 3, fig. 1), like that of a furseal (pl. 3, fig. 2), when viewed from behind, is seen to have essentially the same structure as that which has been found (pp. 7-8) to exist in the disarticulated maxillary of a baleen whale (pl. 3, fig. 3), while that of a fox (pl. 3, fig. 4) might pass, by a series of relatively unimportant changes, into that which is found (pp. 7-8) in the similarly treated maxillary of a toothed cetacean (pl. 3, figs. 5 and 6). The essential feature of difference between the proximal portion of the maxillary of a northern sea-lion or a furseal and that of a fox is that in the seal type the orbital part of the bone is developed outward beyond the alveolar level as a broad horizontal plate (*o. pl.*) independent of the tooth row, while in the fox type it is confined to the region directly above the alveoli; its entire base, in the fox, serves as a support to the teeth, and its outer portion is tilted upward and outward at a conspicuous angle. In the maxillaries of both animals the "malar process" extends along the margin of the orbital plate from the

[1] A further indication of the mechanical weakness of this part of the mysticete skull is the relatively great frequency with which weathered or fossil specimens are found lacking the rostrum.

postero-external angle of the plate to a point distinctly above the antorbital foramen. To develop the baleen whale type from a starting point at which the structure resembled that which is now present in the furseal or sea-lion it is merely necessary to suppose that the pressing together of the orbital plate of the maxillary and the expanding postorbital process of the frontal may have forced the jugal bone to abandon its connection with all of the "malar process" of the maxillary except the lowest, most posterior portion. The development of the toothed cetacean type from a starting point resembling the fox structure might equally well be conceived as primarily the result of degeneration of the orbital plate accompanying complete elimination of the large teeth to which, in the fox, this plate is intimately adjusted.[1] In the fox the heaviest, widest teeth lie behind the level of the antorbital foramen; but in no modern cetacean are any functional teeth whatever known to occur in this region. With the elimination of the posterior teeth and the subsequent degeneration of the orbital plate in a maxillary resembling that of a fox the posterior portion of the malar process might be expected gradually to disappear, thus cutting away or shriveling up the area of connection for the jugal bone with the maxillary until this area became restricted to the highest, most anterior part of its original extent. The differences just described as distinguishing the maxillary of the fox from that of the furseal or sea-lion may be at least partly connected with the relatively very different size of the eye in the two animals. The wide, horizontal orbital plate of the seal and sea-lion acts as a support to the enlarged eye while the narrow oblique plate of the fox meets all the requirements of a normal eye. The orbital plate's persistence in one suborder of modern cetaceans and its absence in the other may therefore point, perhaps, to a difference in the history of the eye in the two groups.[2]

The foregoing comparison between cetacean structures and the conditions found in living pinnipeds and carnivores must not be misinterpreted as implying an idea of immediate affinity among any of the animals in question; each group appears to have had its own independent history. I do not know of any reason to suppose that a

[1] In the actual ancestors the plate was almost certainly not developed to the extent that it is in the fox; this does not lessen the value of the fox as a convenient illustration of the general mechanical course of the process.

[2] Pütter has recorded various peculiarities of the eye and its accessory structures which appear to have this meaning (Zool. Jahrb., Anat., Vol. 17, pp. 99-402, Nov. 10, 1902).

baleen whale on the one hand, is directly related to a sea-lion, while a dolphin, on the other, is near kin to a fox. No more would it seem reasonable to suppose that the first pair might represent two widely divergent offshoots from one phylogenetic stock while the second pair might represent similar developments from another. My object is merely to show that several fundamental features of difference between the skulls of members of the two suborders of living cetaceans are, in the present absence of evidence derived from fossils, most readily explained by assuming that the ancestral forms of one group, at the time when telescoping was about to begin, had certain critical regions of the skull built on essentially the same lines as the corresponding regions in the skull of the northern furseal or the northern sea-lion, while the forerunners of the other, at the corresponding period of the group's history, had them arranged essentially as they are now seen in the fox. Terms of comparison better both structurally and phylogenetically could without doubt be obtained from the skulls of creodonts; but these fossils cannot be disarticulated for use in preparing illustrations such as those on plates 2, 3 and 4, and I have therefore preferred to limit my detailed morphological studies to recent material. Rather hasty examination of the creodonts in the U. S. National Museum and the American Museum of Natural History (in company with Dr. William K. Gregory) has not resulted in the discovery of any genus in which the furseal-mysticete conditions are clearly marked out. The most that can be said is that these conditions are suggested by the structure of the maxillary in *Sinopa* and others. On the contrary the fox-odontocete type of condition is definitely present in the maxillary of *Hyænodon* and *Pterodon*, in a form which, so far as its actual structure is concerned, appears to be leading toward the anatomical features present in the toothed cetacean type; or, perhaps more properly, the structure in the fossils is one which could give rise to both fox and odontocete types of maxillary through two slightly different courses of modification. The posterior teeth of these creodonts are narrow and are situated close under the anterior base of the zygoma so that there is practically no orbital plate. These features are nearly the same as in *Prozeuglodon* (pl. 4, fig. 1 and pl. 5, fig. 1). Comparison of the skulls of *Prozeuglodon* and *Delphinus* (pl. 5, figs. 1 and 4) and the maxillary bone of *Prozeuglodon* and *Grampus* (pl. 4, figs. 1 and 2) shows that the transition from the earlier to the later type, so far as the particular structures under discussion are concerned, would probably be mainly a matter of simple degeneration of the zygoma accompanying the loss of the posterior teeth and the consequent disuse of the masseter muscle. The outward pushing of the lacrimal beyond the base of the jugal, characteristic of the extreme type of toothed cetacean skull, is already well indicated in the zeuglodont (see especially Andrews's pl. 21, fig. 1, Tert. Vert. Fayûm, 1906). On the other hand, it will at once appear from comparison of the maxillary of a zeuglodont with that of a baleen whale (pl. 4, figs. 1 and 3) that here a transition from the earlier to the later type would involve the inexplicable complication of introducing a large new structure, the freely projecting orbital plate (pl. 4, fig. 3, *o. pl.*), in a position where it meets no recognizable mechanical need, and in a condition which suggests a well advanced stage of degeneration.

THE THREE CETACEAN PHYLA OR SERIES

The facts which have just been reviewed appear to be most simply and fully explained by assuming that the known cetacea represent three distinct lines of descent and that the directions in which these lines were to develop were determined by peculiarities of structure established at or before the beginning of pelagic life. The idea that the phylogeny of the cetacea has been multiserial [1] is not new. In different forms and for various reasons it has been put forward by several authors who have dealt with the question of the group's history. The whole subject has recently been reviewed by Kükenthal (Sitzungsber. Preuss. Akad. Wissensch., Phys.-math. Kl., 1922, pp. 72-87, Meeting of March 16, 1922). As I understand it this assumption does not imply that the separate lines represent convergence from widely different ancestral stocks. Such heterogeneous origin is made to appear improbable by the resemblances between zeuglodonts, baleen whales, and toothed whales in features which are not readily explained as the mere retention of primitive characters or as the separate remolding into similar structure of originally unlike parts applied to a single new and peculiar mechanical use. The auditory

[1] The term *polyphyletic,* often used in this sense, is open to the objection that it has two meanings: *multiserial* and *polygenetic.* Apart from the context, therefore, we can never know whether a "polyphyletic group" is a group consisting of several genetic lines coming up out of the past in a direction parallel with each other and never uniting, or whether it is a group formed by the uniting of several lines coming up from different directions. Ambiguity would be avoided by the consistent use of *multiserial* to express the first idea and *polygenetic* to express the second. For *monophyletic* it might be well to substitute *uniserial.*

bones and the scapula have been alluded to by Winge in this connection (Smithsonian Misc. Coll., Vol. 72, No. 8, p. 48, July 30, 1921). To account for the observed morphological conditions it now appears to me unnecessary to assume that the three points of origin were farther apart than adjacent families in some carnivore-like, perhaps early creodont, stock; one which might have also given rise to the modern carnivores and pinnipeds. When independently beginning to undergo cetacean modifications one of these ancestral forms may be supposed to have had some resemblance to *Pterodon,* with a tendency toward narrowing the cranial portion of the skull similar in character to the tendency which may now be seen in the aquatic *Cynogale* (pl. 7, fig. 1) among the *Viverridæ* but carried to a much greater extreme. It might have led to the zeuglodont type (pl. 5, fig. 1). The two others may have been more like *Palæonictis* in general form of the skull, but with a tendency toward broadening of the cranial region such as that which is now displayed by the aquatic otters among the *Mustelidæ,* thus leading to the modern cetacean type. In these broader-headed animals two sets of peculiarities, somewhat analogous on the one hand to those which I have described as now existing in the fox and on the other to those now found in the furseal and northern sea-lion, might be supposed to have supplied the bases for developing, respectively, the skull of the toothed cetaceans and that of the baleen whales. On account of their apparently essential community of origin and fundamental structure the three series should for the present be regarded as forming a single order. All the known members of each series, including the oldest fossils sufficiently well preserved to merit serious discussion, have developed in strict accordance with the definite, and, as it would seem, mutually exclusive tendencies of their respective groups. These three groups show such entire independence throughout the geological periods during which they are known to occur that, as is generally recognized, they are best treated as distinct suborders. Their characters may be summarized as follows:

KEY TO THE SUBORDERS OF CETACEA

Bones of both rostral and cranial portions of the skull retaining their normal mammalian relationships; braincase narrow and elongate; teeth present in about the maximum normal eutherian number, the hinder ones tending to disappear.................................... ARCHÆOCETI.

[Cheekteeth retaining distinct traces of the inner portion of the crown. *Protocetidæ.*

Cheekteeth without traces of inner portion of the crown

Centra of vertebræ normal............................ *Dorudontidæ.*

Centra of vertebræ greatly elongated.................. *Basilosauridæ.*]

Bones of both rostral and cranial portions of the skull departing conspicuously from their normal mammalian relationships; braincase broad and short; teeth increased above the normal eutherian number or secondarily reduced or absent.

Maxillary with orbital plate present; ascending process of maxillary small and narrow, interlocked with body of frontal, not spreading over the expanded supraorbital process; braincase telescoped chiefly from behind; bones forming wall of narial passage always retaining essentially normal relationships; region of base of mesethmoid roofed over by nasals and by median portion of frontals; teeth present in large numbers in embryos but not known to occur in adults; baleen always present in adults [For key to families and genera see page 20] .... Mysticeti.

Maxillary with orbital plate absent; ascending process of maxillary large and broad, not interlocked with body of frontal, spreading outward over the expanded supraorbital process; braincase not telescoped chiefly from behind; bones forming wall of narial passage usually departing conspicuously from normal relationships; region of base of mesethmoid usually not roofed over by nasals or by median portion of frontals; teeth normally present in adults; baleen always absent [For key to families see page 33] .... Odontoceti.

THE DETAILS OF TELESCOPING AND THEIR RELATION TO CLASSIFICATION

While telescoping in each of the suborders of modern cetacea has followed a course which is very consistent as to its main features the various genera are found to arrange themselves according to stages and minor variations of the process. Each of these special peculiarities of detail is well marked and constant for the genera in which it occurs, a circumstance that would of itself indicate definite importance in classification. This importance is, however, greatly increased by the fact that with every stage or detail of telescoping there is associated, in other parts of the skull and skeleton, a special set of characters which are often so well marked that they would by themselves be sufficient to define the same groups, but which do not necessarily present in their degrees of development any parallelism with the progress of telescoping. Conditions of this kind appear to be most clearly expressed by according family rank to the various groups and by arranging the groups primarily in accordance with the progress of that essential process by which the excessively modified modern cetacean skull seems to have been developed from the ordinary mammalian structure. The course of this advance appears to have been influenced in each individual case by varying combinations of the same two general tendencies which have been seen (p. 4) to underlie the differentiation of the two main types of telescoping.

According to one of these tendencies the forward movement of the posterior elements of the skull seems to have held precedence over the backward movement of the anterior elements; according to the other the opposite seems to have been true. While, within each main type, the predominance of one movement is usually evident, there are phases of each type in which the two movements are so combined as to give rise to a somewhat balanced or less one-sided form of telescoping, and others in which the skull appears as if it may have been first subjected to one movement and later to the other. In a general way these varying conditions are distributed somewhat as follows: occipital thrust conspicuously dominant in the balænoids and less so in the balænopteroids; maxillary thrust conspicuously dominant in most of the odontocetes; the two thrusts more intimately combined in the odontocetes of the physeterine type and *Platanista;* a final occipital thrust subsequent to a strongly developed maxillary thrust in the ziphiids. In the following discussion of the details of telescoping among the cetaceans whose skulls are sufficiently known to show these essential characters the use of expressions conveying the ideas of early and late or before and after, is (unless something else is clearly shown by the context) to be understood as applying to the process and not to time; a very late stage of a process might be quickly reached in one animal at a very early geological time, while an early stage might persist in another animal, or in a different part of the same one, to the present day.

DETAILS IN THE BALEEN WHALES

In the general structure of their skull the baleen whales have departed less widely than the toothed cetacea from the ordinary mammalian type. The choanæ still lie distinctly behind the anterior nares as in other mammals. The bones forming the nasal passage retain a general arrangement which is essentially normal, agreeing with the conditions present in the furseal and sea-lion in their fundamental relationships, including the complete roofing over of the proximal ethmoid region by the nasals and the median portion of the frontals, and the exclusion of the palatine from the anterior wall of the narial passage; primitive features which have for the most part disappeared in all known adontocetes except the agorophiids and physeteroids, where some or all of them may persist. The maxillary retains the orbital portion of the body of the bone, while the rostrum is never developed into the attenuated beak which is characteristic of many though not all toothed cetaceans.

Telescoping with excessively dominant occipital thrust is seen in the genera *Balæna, Eubalæna* and *Neobalæna*. A diagram showing the general relationships of the bones at the vertex is given in figure 1 of plate 8. It is taken from the photograph of a skull of *Eubalæna*, but it will answer sufficiently well for the plan of all three.[1] The occipital shield will be seen to have extended forward to a level distinctly anterior to the orbits and to the articular level of the squamosals, completely excluding the parietal from the dorsal surface of the skull, and reducing the median dorsal exposure of the frontal to a narrow transverse strip of bone; the nasal and nasal branch of the premaxillary lie entirely in front of the orbit and of all of the frontal except its unimportant median angle or projection. The nasals and nasal branches of the premaxillary are thus situated obviously in the rostrum with their posterior margins well in advance of the orbital level; and the base of the rostrum has no appearance of having been pushed back against or into the structures which lie behind it. A transverse line drawn across the dorsal aspect of the skull through the base of the nasal will traverse also the premaxillary and maxillary but no part of the frontal other than the unimportant median projection (this projection is most strongly developed in *Balæna*). Such a relationship of the parts in the base of the rostrum presents no very unusual features as compared with the conditions existing in ordinary land mammals. A slight lengthening of the nasal branch of the premaxillary would bring it about in dogs or cats or various ungulates; it is almost realized in some of the bears and pinnipeds, and it may be seen exactly reproduced so far as essential features are concerned, in squirrels, pocket gophers and other rodents (pl. 8, fig. 8). The side view of such a cetacean skull (pl. 6, fig. 4) shows even more clearly how the post-rostral portion has been overridden by the occipital shield while the rostrum has not interlocked with the structures behind it. The intermaxillary has extended backward to the same level as the base of the maxillary; but neither of these bones shows any tendency to encroach upon the frontal. On the contrary the forward push of the occipital region seems to have crushed the frontal broadly against the maxillary,

[1] In the case of *Neobalæna*, the skull of which I have not seen, I have based my comparison of the conditions existing in the region of the vertex on the figures published by Hector (Trans. and Proc. New Zealand Inst., Vol. 2, pl. 2B, 1869) and Oliver (Proc. Zool. Soc London, 1922, Oliver, pl. 1, September, 1922). They appear to have been made from a better point of view than the one published by Beddard (Trans. Zool. Soc. London, Vol. 16, pl. 8, 1901).

flattening the posterior border of the latter bone until in the region of the ascending process there is nothing more than a broad postero-superior angle. These peculiarities may be due in part to the arching which the skull has undergone in connection with the development of the greatly elongated plates of baleen within the mouth cavity; but, whatever their origin, they appear to have resulted in modification almost exclusively through forward overthrust and movement from behind. Of the genera in which this kind of telescoping has taken place *Balæna* and *Eubalæna* present the extreme of specialization in the development of the food-straining apparatus, a specialization which involves increase in the size of the head as compared with that of the body, and a great upward-arching of the whole skull accompanied by lengthening of the baleen plates and enlarging of the suspension area for the lower jaw. In *Neobalæna* on the other hand the skull is moderately arched, and the form of the rostrum is peculiar among the living baleen whales; broad at the base and narrowing rapidly to an attenuate tip; mandible excessively robust, strongly bowed outward. The rib-bearing portion of the vertebral column in *Neobalæna* shows the maximum condition of development known in the group, but the cervicals are completely fused with each other, and the hinder part of the column is so remarkably reduced by suppression of some of the caudals and all but two of the lumbars that the number of vertebræ behind the dorsals does not exceed that of the dorsals themselves, while in all other baleen whales it is at least twice that of the dorsals. The ribs are large and broad, but all except three or four at the anterior end of the series are unattached to the vertebræ, a condition not known in other whalebone whales. These characters of *Neobalæna* indicate such a fundamental divergence on the part of this genus from *Balæna* and *Eubalæna* that it should be placed in a separate family.

In all of the other mysticete genera except the extinct near relatives of the balænids the backward movement of the anterior elements of the skull appears to have been an important part of the process of telescoping. The nasal bones and the nasal branches of the premaxillaries are no longer situated obviously and conspicuously out in the rostrum. Their bases are forced back to or beyond the level of the anterior border of the supraorbital portion of the frontal, thus finally reaching a position which they do not occupy in any known land mammals and which gives them the appearance of belonging to the facial part of the skull.

The extinct genus *Cetotherium* and its allies represent the least modified known stage (pl. 8, fig. 2). The anterior point of the occipital shield lies decidedly behind the level of the orbit as well as of the anterior margin of the articular portion of the squamosal, while in front of the shield the parietals come into contact with each other on the vertex, usually forming a distinct transverse band in front of the occipital shield. Beyond the parietals the frontals also cross the vertex as a wide band. They pass directly and broadly into the supraorbital processes. A peculiarity which distinguishes the skull of *Cetotherium* and its allies from that of all the other known baleen whales is the gradual slope of the supraorbital process from the dorsal level of the interorbital region downward and outward toward the margin of the orbit. In all other members of the suborder the basal part of the process is abruptly and conspicuously depressed below the median dorsal level, so that the main outwardly-extending dorsal surface of the process is more nearly horizontal in position.

In the genus *Rhachianectes* a more advanced stage (pl. 8, fig. 3) is represented. On comparing the diagrams it will be seen that this stage is readily derived from the last. The principal peculiarities as compared with *Cetotherium* are that the supraorbital process of the frontal is broader at base (where it is abruptly depressed below the dorsal level), the nasal is greatly enlarged, the nasal processes of the maxillary and intermaxillary are lengthened, and the overthrust of the occipital shield, while not enough to carry the front of the shield beyond the level of the anterior margin of the articular portion of the squamosals, has progressed forward sufficiently to push apart the parietals on the vertex, where, however, these bones are transversely united by a narrow band of interparietal. Interdigitation of frontal, maxillary, intermaxillary and nasal is well marked, but it is not sufficiently seconded by forward thrusting of the elements of the braincase to involve the parietal. This bone is broadly exposed on the surface of the braincase along the inner side of the temporal fossa, its extremity just appearing on the vertex. It lies entirely behind the nasals and the nasal branches of the intermaxillaries and maxillaries. It is behind the frontal everywhere except in the region where the supraorbital portion of the frontal joins the part which is exposed on the vertex. Here the parietal sends forward a very short, wide, triangular process which interlocks with the frontal. In many important details of structure *Rhachianectes* stands apart from all the known whalebone whales both recent and fossil. The nasals are larger than in any other known cetacean. Notwithstanding the large area which the nasals occupy, the frontals, owing to the slight forward extension of the occipital shield and the exclusion of the parietals from the middle of the vertex, share with *Cetotherium* and its allies the maximum known degree of exposure on the vertex. The surface of the relatively small occipital shield is noticeably tuberculate-roughened for muscle attachment. The rostrum and jaws have been developed according to tendencies different from those seen in other whalebone whales: rostrum moderately arched, rather narrow at base, gradually tapering, straight-sided, and with a general inclination to deepening rather than to widening; intermaxillaries conspicuously produced upward above maxillaries to form a raised rim to the nasal cavity; mandible very heavy, and so remarkably little bowed outward that a straight line can be drawn from its base to its tip without passing conspicuously outside of the general contour; no definite coronoid process. The portions of the skull serving as suspensorium to this unusually heavy mandible are smaller and less specialized than in any of the other living baleen whales.

The most extreme stage of the mysticete type of telescoping (pl. 8, figs. 5, 6, 7) is found in the finbacks and humpback. In all of these whales, as in *Balæna, Eubalæna* and *Neobalæna,* the occipital shield is carried forward beyond the level attained by the anterior part of the articular processes of the squamosal, a peculiarity which immediately distinguishes them from the living *Rhachianectes* and the extinct cetotheres. The general interlocking of the rostrum with the cranium is in some respects like that which has been seen in *Rhachianectes.* But it has gone a definite step farther; accompanying the forward extension of the occipital shield the pointed antero-external termination of the parietal, which projects slightly into the frontal of *Rhachianectes,* has now been developed as a thin plate extending far forward along the inner wall of the cavity above the orbital wing of the frontal (pl. 6, fig. 3) in a direction parallel with the nasal and nasal branches of the intermaxillary and maxillary, the level of whose bases it overlaps. In the less pronounced examples of this type (pl. 8, figs. 5 and 6) seen in *Balænoptera* and *Megaptera* a distinct strip of the frontal, lying between the forward-projecting plate of the parietal and the backward-projecting nasal process of the maxillary, connects the supraorbital wing with the narrow exposure of the frontal on the vertex; but in the more pronounced condition (pl. 8, fig. 7) present in *Sibbaldus* the frontal practically disappears from the surface of this part of the skull, the parietal almost applies itself to the outer margin of the nasal branch of the maxillary,[1] and the occipital shield comes in contact with the maxillary, premaxillary and nasal. A definite set of other characters is associated with these final stages of telescoping. The straining-bag formed by the mouth is increased in capacity not by an arching of the rostrum as in the balænoids, but by a bowing outward of the lower jaws, a broadening and flattening of the rostrum, and a longitudinal folding of the skin of the entire throat and underside of the mouth to allow for great distention. While the jaw is not conspicuously increased in size relatively to the size of the skull the parts of the cranium serving as its suspensorium are enlarged and specialized to a greater degree than in *Rachianectes*. The characters just enumerated distinguish this group of genera as a family separate from the four other families of baleen whales. Within the limits of the group the humpbacks, *Megaptera*, are sharply contrasted with the finbacks, *Balænoptera* and *Sibbaldus*, by the unusual structure of the scapula and by the great elongation of the manus. In the finbacks the scapula retains the form characteristic of the baleen whales in general: the coracoid and acromion are large, functional processes. In the humpbacks the processes are reduced to mere tubercles. Humpbacks and finbacks differ from each other sufficiently to be regarded as the representatives of two subfamilies.

The more important characters of the genera and higher groups of baleen whales are tabulated in the following key:

KEY TO THE FAMILIES AND GENERA OF BALEEN WHALES

Telescoping of skull accomplished chiefly by forward movement of posterior elements; interdigitation of rostral and cranial elements of skull absent or slight, the nasals and nasal branches of the intermaxillaries situated entirely anterior to the level of the orbital wings of the frontals; no definite "nasal process" of maxillary ever present (Balænoids).

Supraorbital wing of frontal narrow, its antero-posterior diameter at middle less than one-third its transverse diameter; rostrum so highly arched that a straight line cannot be drawn from its extremity to any part of its base without passing outside of the general contour; general outline of rostrum when viewed from above attenuate; most of the ribs attached to the vertebræ; lumbar vertebræ 10 or more. BALÆNIDÆ.

[1] In a 20-foot skull of *Sibbaldus musculus* (No. 49757, U. S. Nat. Mus.) the upper edge of the parietal rises to the same level as the dorsal surface of the maxillary; it is separated from the maxillary by a groove about 10 mm. wide and 20 mm. deep, at the bottom of which can be seen the superior margin of the frontal.

Entire skull when viewed from the side arched more abruptly at base than in rostral portion, the general curve therefore not approximately following the arc of a circle; length of skull contained about three times in length of vertebral column; depth of skull from highest part of arch to lower border of mandible less than greatest depth of thorax........................*Eubalæna.*

Entire skull when viewed from the side arched rather uniformly in a curve which approximately follows the arc of a circle; length of skull contained about one and one-half times in length of vertebral column; depth of skull from highest part of arch to lower border of mandible conspicuously greater than greatest depth of thorax..*Balæna.*

Supraorbital wing of frontal broad, its antero-posterior diameter at middle more than one-half its transverse diameter; rostrum so slightly arched that a straight line can be drawn from its extremity to its base without passing outside of the general contour; general outline of rostrum when viewed from above tapering rapidly from a broad base to slender tip; most of the ribs free from the vertebræ; lumbar vertebræ 2 (*Neobalæna* only)..................NEOBALÆNIDÆ.

Telescoping of skull accomplished by a combined forward movement of posterior elements and backward movement of anterior elements which produces at least some obvious indication of interdigitation between rostral and cranial elements; nasals and nasal branches of premaxillaries not situated entirely anterior to the level of the orbital wings of the frontals; a definite "nasal process" of the maxillary always present (Balænopteroids).

Parietal entirely behind posterior level attained by nasals and nasal branches of maxillaries and intermaxillaries; occipital shield not extending forward over level of orbit or beyond anterior level attained by articular portion of squamosal; frontal broadly exposed on vertex; expanded lateral (articular) portion of squamosal relatively small, its under surface not deeply concave.

Supraorbital process of frontal sloping gradually downward and outward from level of dorsal surface of interorbital region; parietals coming in contact or nearly so on vertex between occipital shield and frontal; nasals small (normal), their combined dorsal area equal to much less than half that of supraorbital portion of frontal; rostrum tending toward breadth rather than depth; mandible slender, conspicuously bowed outward (*Cetotherium* and related genera).................CETOTHERIIDÆ.

Supraorbital process of frontal abruptly depressed at base to a level noticeably below that of dorsal surface of interorbital region; parietals not coming in contact or nearly so on vertex between occipital shield and frontal; nasals greatly enlarged, their combined dorsal area equal to more than half that of supraorbital portion of frontal; rostrum tending toward depth rather than breadth; mandible heavy, slightly bowed outward (*Rhachianectes* only) ........................RHACHIANECTIDÆ.

Parietal extending forward laterally beyond posterior level attained by nasals and nasal branches of maxillaries and intermaxillaries; occipital shield extending forward over level of orbit and beyond anterior level attained by articular portion of squamosal; frontal scarcely or not exposed on vertex; expanded lateral (articular) portion of squamosal relatively large, its under surface deeply concave [supraorbital process of frontal abruptly depressed at base to a level noticeably below that of dorsal surface of interorbital region; rostrum tending toward breadth rather than depth; mandible conspicuously bowed outward] .... BALÆNOPTERIDÆ.

Scapula with acromion and coracoid processes rudimentary [Rostrum and frontal with general relationships as in *Balænoptera*] (*Megaptera* only) .... MEGAPTERINÆ.

Scapula with acromion and coracoid processes well developed. BALÆNOPTERINÆ

Rostrum approaching maximum development, triangular in outline when viewed from above, its sides straight or slightly and evenly curved; telescoping of braincase nearly at maximum, the portion of frontal exposed on vertex of skull narrow but evident .... *Balænoptera*.

Rostrum at maximum known development, its sides parallel with each other through most of basal half, then rather strongly curved to tip; telescoping of braincase at maximum, the portion of frontal exposed on vertex of skull so narrowed that parietal is essentially in contact with maxillary, and occipital touches base of nasal .... *Sibbaldus*.

DETAILS IN THE TOOTHED CETACEA

In general structure of the skull the toothed cetacea have departed more widely than the baleen whales from the ordinary mammalian type. Except in members of the extinct family *Agorophiidæ* the anterior nares have been forced back over the choanæ so that the arrangement of the bones forming the nasal passage is no longer essentially normal; the proximal ethmoid region is completely exposed from above (pl. 1, fig. 1*a*), without over-roofing by the nasals or by the median portion of the frontals; the palatine takes part in forming the anterior wall of the narial passage. The maxillary (pl. 1, fig. 1*b*) has no trace of a horizontal orbital plate, even, apparently, in the peculiar genera just alluded to. The rostrum is often developed into a slender beak widely different in character from the corresponding part of the skull in any other mammals. While the process of telescoping in this group has without exception followed the general course whose main features have already been described (p. 4, etc.), the two chief variations in this course appear to be almost as clearly indicated as in the case of the baleen whales. In one (pl. 5, figs. 4, 5; pl. 7, figs. 2, 4) the backward thrust of the maxillaries seems to have been either more pronounced than the forward thrust of the occipital or to have reached advanced stages of development earlier in the process of telescoping than the period when the forward advance of the occipital became conspicuous; in the other (pl. 6, figs. 1, 2; pl. 7, fig. 3) the discrepancy between the two movements is less obvious, and their share in the remodeling of the skull appears to have been less unequal. One of the most noticeable results of the first tendency has been to carry the maxillary back in such a manner that the frontal, except in the orbital rim, is practically excluded from view in the region lying above and behind the eye; at most it may be visible as a band of varying width extending upward and backward along the margin of the temporal fossa behind but not over the orbit (pl. 5, figs. 4, 5; pl. 7, fig. 4). The second tendency, on the contrary, brings about conditions in which a relatively wide area of the frontal is visible in the region directly above the orbit (pl. 6, figs. 1, 2; pl. 7, fig. 3). Each of these tendencies has been worked out in great detail; the dominant maxillary thrust is particularly well shown in *Stenodelphis* (pl. 7, fig. 2), the more balanced condition in *Kogia* (pl. 7, fig. 3). Contrary to what might be expected it is the second tendency which has led to the development of the cetacean skulls (pl. 6, fig. 2, and pl. 7, fig. 3) whose structure is most fundamentally removed from a characteristic terrestrial mammalian type (pl. 7, fig. 1).

The least modified structure positively known to exist occurs in the genera *Agorophius* (pl. 5, fig. 2), *Archæodelphis* (pl. 5, fig. 3), and *Xenorophus* (pl. 5, fig. 6), the first and third from the Eocene or Oligocene of South Carolina, the second perhaps from the same region and horizon.[1] The skull is broad and short (for dorsal view of *Agorophius* see True, Remarks on the type of the fossil cetacean *Agorophius pygmæus* (Müller), Smithsonian Inst., Publ. No. 1694, 1907. For other figures of *Archæodelphis* see G. M. Allen, Bull. Mus. Comp. Zool., Vol. 65, No. 1, August, 1921). The process of telescoping is well advanced and strictly of the modern odontocete type. The occipital, however, contrary to the conditions existing in all other known toothed cetaceans except the zeuglodonts, has not yet extended far enough forward to meet the frontal. The parietals are therefore still present on the vertex of the braincase, where they form the roof of a short but obvious postorbital constriction the width

[1] An essentially similar structure may be present in *Patriocetus* from the Oligocene of Austria; but the published facts concerning this genus are not sufficiently conclusive to warrant any generalizations (see pp. 42-44).

of which, in *Agorophius* at least (the skulls of the two other animals are imperfect in this region), is equal to about one-third or one-fourth the greatest width of the skull. (The entire braincase of *Xenorophus* is lost, but the essential agreement with the two other genera is shown by the structure of the orbits and the interorbital region.) In this character there is a close analogy with the condition present among the *Cetotheriidæ*. The maxillary in two of the known specimens is imperfect. It is sufficiently well preserved, however, to show that in *Agorophius* and *Xenorophus* it had already overridden the frontal in very much the same manner as that which is normally seen in porpoises, and to such an extent that it overlaps the anterior edge of the temporal fossa, while in *Archæodelphis* it has apparently not pushed backward quite to the level of the posterior border of the orbit. In *Archæodelphis* the maxillary is described and figured as forming part of the anterior orbital rim, a generalized mammalian feature not known in any other odontocete. In *Xenorophus* the maxillary is excluded from the orbital rim by the jugal. Which of these two conditions existed in *Agorophius* the type specimen was too much damaged to show. Other primitive features known to occur in *Archæodelphis* and *Xenorophus* but not demonstrable in the figures of *Agorophius* are connected with the narial passage. This passage slopes backward essentially as in the baleen whales; the proximal ethmoid region is roofed by the nasals and the median portion of the frontals; the palatines form no part of the anterior wall of the narial passage, thus agreeing with the structure present in normal mammals, baleen whales, and physeterine toothed whales. While it appears unlikely that a family existing so recently as the upper Eocene or lower Oligocene could have been genetically ancestral to any considerable number of cetacean types, two of these early odontocetes seem clearly to represent morphological stages of development through which the ancestors of some of the modern toothed cetacea might have passed. I think it can be appreciated after comparing the skull of *Agorophius* (pl. 5, fig. 2) with that of recent *Delphinus* (pl. 5, fig. 4) that a structure like that which is seen in the living delphinoids might not improbably have been developed from the one present in the fossil by a process which consisted primarily in a forward movement of the occipital region until the supraoccipital came in contact with the upper margin of the frontal, and the anterior extremity of the articular portion of the squamosal arrived at a point beneath the tip of the postorbital process. Similarly the relationship of the maxillary to the orbit and frontal in *Archæo-*

delphis might be regarded as giving some hint of an early stage in the development of conditions like those now seen in *Platanista* (pl. 6, fig. 2) and the physeterines (pl. 6, fig. 1; pl. 7, fig. 3). In the genus *Xenorophus,* however, specialization appears to have advanced in directions which have not been followed by later members of the group. This is shown by the wide spreading of the lacrimal over the supraorbital process of the frontal to the level of the hinder margin of the eye; by the abrupt widening of the intermaxillary in the region behind the narial aperture, this widened portion forming a thin plate spreading outward underneath the maxillary over apparently the basal half of the supraorbital process; and finally by the very abrupt and conspicuous depression of the maxillary in the region immediately in front of the orbit, the sudden slope thus formed giving the horizontal portions of the bone lying respectively above the orbit and above the roots of the teeth (in the regions marked *mx* and *a. pr,* pl. 5, fig. 6) somewhat the profile of upper and lower river terraces separated by an escarpment. The under-thrust premaxillary appears to have no analogue in other known odontocetes. In some living genera (*Pseudorca, Globicephala*) the lacrimal sends up a thin, inconspicuous ridge-like process closely applied to the curved anterior border of the supraorbital process and occasionally extending over the rim of the process to the extreme anterior edge of the dorsal surface. Such a structure might be interpreted as the last trace of a backwardly spread portion of the lacrimal like that of *Xenorophus* which had been almost obliterated by a subsequent outward-extending of the maxillary. In *Stenodelphis* the maxillary shows a slight trace of terraced structure, but I do not find it present in other living genera. The most natural explanation of this structure seems to be a depression of the rostrum subsequent to a backward extension of the maxillary in a horizontal direction over the orbit.

Another stage is found in all of the remaining known members of the suborder, living and extinct, except *Platanista, Physeter* (with its extinct relatives), and *Kogia;* this statement naturally not applying to fossils so imperfectly preserved that the characteristic strucures cannot be determined. The braincase has now enlarged and the upper margin of the occipital has come into contact with the frontal; thus the postorbital constriction has been obliterated and the parietal has been excluded from the vertex (pl. 1, fig. 1*a*). The maxillary extends backward over the frontal nearly or quite to the anterior margin of the occipital. Laterally it may (pl. 1, fig. 1*a*) or may not spread out so as to cover practically the entire dorsal surface of the supraorbital process of the frontal; but its position in the region directly over the middle of the orbit is always (see particularly the constancy of this feature in two such diverse types as *Stenodelphis* and *Hyperoodon*, pl. 7, figs. 2, 4), like that of the dorsal surface of the expanded process, essentially horizontal in striking contrast to its oblique position in *Physeter, Platanista* (pl. 6, figs. 1, 2) and *Kogia* (pl. 7, fig. 3). The orbital cavity, in other words, is roofed over, at least in its median portion, by two flattened plates of bone which lie in or nearly parallel to a plane representing the backward prolongation of the median horizontal plane of the rostrum. With the crushing together of the anterior and posterior elements of the skull the narial passages have been forced back so that they occupy an almost vertical position closely following the contour of the convex outer side of the anterior wall of the braincase, down which they extend like a pair of gutter pipes. The nasals and the median portion of the frontals (pl. 1, fig. 1*a*) have been pushed backward until they no longer roof the proximal ethmoid region. The palatine has a much reduced exposure on the roof of the mouth (pl. 1, fig. 1*b*) ; but it has developed a large new narial plate which forms an important part of the anterior wall of the narial passage.

This stage of telescoping is found in the great majority of members of the suborder. It was fully established in the Miocene of both Europe and America; and its fundamental importance seems clearly indicated by the fact that it has remained constant in animals whose skulls and dentitions have diverged in other characters as strikingly as those of *Squalodon* and *Monodon, Eurhinodelphis* and *Orcella,* or *Hyperoodon* and *Orcinus*. That it should present numerous secondary degrees and variations of development would, however, be expected. The conditions which in some respects are the least far removed from the ordinary mammalian type and from the *Agorophiidæ* are most clearly shown by the extinct *Squalodon* and the existing genera *Inia* and *Lipotes*. Here the braincase, though relatively larger than in *Agorophius* and *Archæodelphis,* has not reached its maximum development, and the region of juncture between the occipital and frontal bones has not pushed forward into any noticeable proximity to the level of the orbit; a considerable part of the frontal remains visible on the side of the braincase; the temporal fossa has not suffered marked reduction (its size, when the skull is viewed from behind, obviously exceeds the combined area of the occipital condyles and the foramen magnum). A slight variation of this condition occurs in *Stenodelphis* (pl. 7, fig. 2) : frontal conspicuously exposed on side of braincase, but area of temporal fossa considerably reduced through the drawing inward of the large articular processes of the squamosal. In *Monodon* and *Delphinapterus* the region of contact between the occipital and frontal is about as far behind the level of the orbit as in *Squalodon* or *Stenodelphis,* but the braincase has become so much enlarged that it causes a marked reduction of the temporal fossa (the fossa, when skull is viewed from behind, is obviously smaller than the combined area of the occipital condyles and the foramen magnum) and very considerably reduces the area of the frontal exposed on its side. A condition whose main features apparently resemble those found in *Monodon* and *Delphinapterus* seems to occur in most of the Miocene dolphins. Such material as I have examined (representing several genera) from the Calvert formation of Maryland agrees with these two living genera and with the published figures of skulls from the Antwerp Crag in the great backward extension of the maxillary behind the orbit and the posterior position of the region of contact between the occipital and frontal. In these extinct dolphins the size of the temporal fossa appears to be reduced as compared with the condition seen in *Squalodon, Inia* and *Lipotes;* but the state of preservation of the specimens makes it unsafe to generalize on the subject. The area of the frontal exposed on the side of the braincase also seems to have undergone the corresponding restriction. It must always be remembered, however, that characters of this kind are easily obscured by the crushing and other injuries which fossils usually have suffered. Returning to the recent genera we find that in all of those not previously mentioned among the types showing dominance of the maxillary thrust (that is in all except *Inia, Lipotes, Stenodelphis, Monodon,* and *Delphinapterus*) the posterior border of the maxillary has not been carried very far behind the level of the orbit, and at the same time the region of contact between the occipital and frontal has been advanced to a position not conspicuously behind the posterior orbital level (compare *Delphinus,* pl. 5, fig. 4 with *Stenodelphis,* pl. 7, fig. 2). This condition might be interpreted as a regression of the hinder maxillary edge under the influence of forward pressure of the occipital; but I am inclined to believe that in most instances it really indicates a course of development independent from that which was followed by those members of the group in which the maxillary reached its extreme backward extension. Had the hinder margin of the maxillary been secondarily pushed toward its original position by a forward-advancing occipital some overlapping, or at least a strong tendency to unusually close contact of the two bones, would be expected to occur; but no such conditions are found, except, perhaps, among the ziphiids (pl. 5, fig. 5; pl. 7, fig. 4), where the forward curling of the posterior extremity of the maxillary suggests the possibility of development through secondary occipital encroachment on a structure previously resembling that of *Stenodelphis* (pl. 7, fig. 2). With this possible exception the developmental tendency of all these recent genera appears to have been less strongly dominated by the backward thrust of the maxillary than in *Inia, Lipotes, Stenodelphis, Monodon,* and *Delphinapterus;* the braincase has enlarged more freely, and the area for attachment of the neck muscles has been increased by some forward extension of the occipital beyond the level of the condyle (compare the occipital of *Delphinus,* pl. 5, fig. 4, with that of *Stenodelphis,* pl. 7, fig. 2). This combination has given rise to the most efficient and successful of all cetaceans, the recent dolphins, a type which shows great plasticity and at the same time little tendency toward extravagance and gigantism. Some of the more conspicuous results to which this plasticity has led are as follows. In the ziphiids (the fundamental similarity of whose skull to that of the delphinids may be seen on comparison of pl. 5, figs. 4 and 5) the beak tends to be deepened and solidified into a peculiar and characteristic form; the upper teeth have disappeared as functional organs; most of the lower teeth have similarly disappeared while the few that remain have been enlarged and specialized; the region of contact between the occipital and frontal is unusually elevated and is situated not far behind the orbital level (see the point marked + in fig. 5, pl. 5, and fig. 4, pl. 7); the entire posterior part of the skull seems to have advanced forward; the maxillary appears to turn secondarily forward in its hindermost and uppermost part (see especially pl. 5, fig. 5); the lacrimal is free from the jugal; the pterygoid is greatly enlarged, but its reduplications are represented by mere ridges; the hindermost ribs are supported by transverse processes which have peculiarities making them seem to be perhaps not serially homologous with those which support the others, the change taking place abruptly between two contiguous vertebræ ranging in position from the 6th and 7th (*Hyperoodon;* two processes visible on the 7th dorsal vertebra) to the 10th and 11th (*Berardius*). In the delphinoids the beak may be lengthened or broadened, but it is never deepened and solidified as in the ziphiids; the lacrimal is fused with the jugal; the pterygoid is not specially enlarged and its internal reduplication is well developed (pl. 5, fig. 4); the hindermost ribs are supported by transverse processes which ordinarily, in living forms at least, have no obvious peculiarities making them appear to be not serially homologous with those which support the others. Normally the intermaxillary does not extend forward much beyond the maxillary, but in the extinct eurhinodelphines it is said to be so greatly produced as to form about one-third of the excessively attenuate beak (I do not regard the published evidence as conclusive; see pp. 49-50). The teeth are of two types. In the more usual form, found in most of the *Delphinidæ* except *Delphinapterus* and *Mondon,* their structure and method of growth is like that of simple conical teeth in other mammals; that is, the crown consists of a dentine shaft capped with enamel and with or without a deposit of cement on the lower portion; the pulp cavity closes when the tooth has reached its full size, and the crown gradually wears down to the level of the gum. In the other form their structure and method of growth are tusk-like; that is, the enamel cap is so reduced as to be visible in very young teeth only, and to be of no functional importance at any time,[1] while the cement is so increased that it becomes a conspicuous mechanical portion of the shaft of the tooth; the pulp cavity remains open throughout much or all of the animal's life, and the wearing away of the crown is continually compensated for by new growth from below. This tusk-like type of growth occurs in its typical condition in *Delphinapterus* (described and illustrated by Lönnberg, Arkiv för Zoologi, Vol. 7, No. 2, July 5, 1910), where each moderate sized functional tooth in the adult is the constantly worn down base of a tusk, which, if entire, would be not less than 120 mm. in length when fully grown. The enormously enlarged tusk of the male *Monodon* appears to be a development from a tooth of this kind. Modifications of an essentially similar tusk-like condition are found in the beaked whales as well as in the more distantly related *Physeteridæ* and *Kogiidæ,* and in several fossils of doubtful affinity.

Though the toothed cetacean type which seems to be the most efficient has been developed by those members of the group in which the maxillary bone passes horizontally backward over the entire

[1] Flower says of some young sperm whale teeth about 40 mm. in length: ". . . . they show no trace of an enamel covering to the apex, a point which has hitherto been one of uncertainty" (Trans. Zool. Soc. London, Vol. 6, p. 325). Teeth 10 mm. and 15 mm. long in the U. S. National Museum (No. 49488) show irregular patches of a substance which appears to be enamel at the extreme tip and scattered over the rapidly tapering terminal half of the crown. These patches probably represent the last remnants of the degenerating enamel cap.

width of the orbit, the type which represents the most extreme structural departure from normal mammals is realized among those toothed cetaceans in which the maxillary bone passes obliquely upward and backward from the orbit's anterior margin (pl. 6, figs. 1 and 2; pl. 7, fig. 3; compare especially the skull of *Kogia,* pl. 7, fig. 3, the genus in which these peculiarities are most obvious in the lateral view, with that of a normal mammal, pl. 7, fig. 1). Whatever may have been its origin this second type of telescoping appears to be not mechanically derivable from a condition in which the orbit had first been roofed by two plates in horizontal position (compare *Kogia,* pl. 7, fig. 3, with *Stenodelphis,* pl. 7, fig. 2, and *Hyperoodon,* pl. 7, fig. 4). Telescoping by this system carries the maxillaries upward and backward from the anterior margin of the orbit at an angle of from 50 to 70 degrees above the line representing the backward prolongation of the rostral axis and leaves the frontal broadly exposed in the region lying above and behind the eye; the orbit is immediately roofed by a thick mass of the frontal alone, and not, as in the more usual type of telescoping, by two thin approximately horizontal plates, one formed by the frontal and the other by the maxillary. An explanation of these conditions appears to demand the presence of some factor radically different from those which brought about the development of the typical dolphin type. Seemingly at a stage when the maxillary had not yet been forced back over the orbit, the occipital, and with it the entire braincase, may have been pressed forward sufficiently to have modified the primitive form of the supraorbital region of the frontal seen in the orbital roof of *Prozeuglodon* (pl. 5, fig. 1) and retained in ordinary dolphins (as in pl. 5, figs. 4 and 5), by elevating it posteriorly so that it no longer lay in its original approximately horizontal position. Thus when the maxillary, in its backward movement, reached the mid-orbital level it would have been made to slope upward away from the anterior edge of the orbital rim by a previously established upward slope of the frontal. While this hypothesis is not based on any observed intermediate stages of structure, and may therefore prove to be entirely wrong, it appears to offer an explanation that involves fewer difficulties than those which are met in any attempt to show that the conditions found in the sloping type could have been developed after the maxillary had first established itself over the orbit in a horizontal position. Another possibility which must be considered is suggested by the structure which appears to exist in *Archæodelphis* (pl. 5, fig. 3). In the only known specimen of this animal the rostrum is broken away at its base, but the remaining portion indicates that the entire rostrum was so depressed that its upper margin lay at a level slightly if at all superior to that of the upper margin of the occipital condyle, much as in *Platanista* (pl. 6, fig. 2). Such a depression of the rostrum at a period when the backward advance of the maxillary was beginning might conceivably place the telescoping elements in such a position as to initiate an upward slope from the anterior orbital rim, the eye acting as a pivot. Depression of the rostrum after an extensive backward movement of the maxillary had taken place would be expected to result in the terraced condition of the maxillary seen in *Xenorophus* (pl. 5, fig. 6) and less conspicuously in *Stenodelphis*.

One form of this kind of telescoping occurs in *Platanista* (pl. 6, fig. 2). The maxillary rises from the front of the orbit at an angle of about 50 degrees; the occipital extends far forward in the median region, but at the side it is held back by the rather large parietal. Associated with these peculiarities there occurs a remarkable combination of special characters. The edge of the maxillary above the orbital region is developed into a high thin plate apparently homologous with the maxillary ridge present in *Physeter, Kogia, Hyperoodon* and elsewhere (compare especially pl. 6, fig. 2, with pl. 7, fig. 4), but so unusually large and of such peculiar form that, with its fellow of the opposite side, it completely arches over the front of the face and incloses the space occupied by the oily facial cushion[1]; the squamosal portion of the zygoma is extremely large and the jugal is correspondingly short; the pterygoid is spread laterally so as to cover the alisphenoid, and its outer plate is so developed as to be an almost exact duplication of the inner plate, the two plates everywhere closely approximated, the space between them occupied by a loose network of bony filaments; palatines widely separated from each other by the vomer, each entirely covered by the two plates of the pterygoid except where it appears on the surface in the anterior wall of the essentially vertical narial passage; infraorbital foramen situated at a level conspicuously behind the much reduced orbit. The teeth, though unusual in form, are normal in structure; the relationship of the ribs to the vertebræ is the same as in the *Delphinidæ,* that is, all the ribs are supported by serially homologous transverse processes.

Another form occurs in the sperm whale (pl. 6, fig. 1). Here the frontal and maxillary are essentially like those of *Platanista,* but the occipital and the squamous portion of the squamosal have advanced laterally to a level not far behind the orbit, thus reducing the parietal

[1] Hinton and Pycraft (Ann. and Mag. Nat. Hist., ser. 9, Vol. 10, p. 234, August, 1922), have suggested that these plates originated as bony stoppers to the blow hole.

to a small element not visible in adults but appearing in very young skulls (like the one figured) as a thin cap overlying the upper portion of the squamosal. Associated characters are: an enormously developed facial depression; a heavy jugal unlike that of any other known toothed cetacean, and suggesting, in its robustness, the jugal of the baleen whales; a long rostrum much widened by building out the sides beyond the level of the tooth row, and strikingly contrasted with a narrow lower jaw with extremely long symphysis; an unusually large occipital condyle extending upward to involve the supraoccipital; palatine large, essentially normal in position, not forming any part of the anterior wall of the slightly backward-sloping narial passage; pterygoid spreading forward over much of the palatine, but not extending laterally over the alisphenoid and not developing any secondary plate; maxillary teeth present in young only, their position normal with regard to the lower toothrow (not carried outward by the widening of the rostrum as has been suggested); mandibular teeth large, tusk-like in structure and in manner of growth; hindermost ribs supported by transverse processes which are perhaps not serially homologous with those which support the others.

The most advanced stage, so far as the upper portion of the skull is concerned, is reached by *Kogia* (pl. 7, fig. 3). The parietal is now obliterated as a separate element, even in skulls so young that the bones of the cranium are readily disarticulated, and the summit of the occipital has been carried forward to a level nearly over the posterior border of the orbit. The median region of the frontal, underneath the maxillary, has largely disappeared, so that a considerable part of the anterior wall of the braincase is seen, on disarticulation of the skull, to be formed by the maxillary. In contrast with *Physeter* the entire skull is shortened and the facial depression is less extremely developed relatively to the occipital depth; the jugal is represented by its anterior extremity only, not distinguishable from the lacrimal except in very young individuals; the symphysis mandibuli is short, and the form of the lower jaw as a whole presents no contrast to the short, wide rostrum; occipital condyle not unusually large and not extending upward to involve the supraoccipital. The structure of the palatine and pterygoid resembles that present in *Physeter;* the narial passage slopes slightly backward; the teeth are tusk-like in structure and in manner of growth; the hindermost ribs are supported by transverse processes which may not be serially homologous with those which support the others.

The more important characters of the supergeneric groups of modern toothed cetaceans are tabulated in the following key:

KEY TO THE FAMILIES AND SUBFAMILIES OF TOOTHED CETACEA

Combined enlarging of brain and pushing together of braincase and anterior part of skull so little advanced that a distinct trace of the primitive postorbital constriction remains visible from above; parietals in contact on vertex behind frontals; maxillary sometimes (in *Archæodelphis*) forming part of anterior rim of orbit [palatine normal in position, not forming part of anterior wall of backward-sloping narial passage] (*Agorophius, Archæodelphis* and *Xenorophus*) .... AGOROPHIIDÆ.

Combined enlarging of brain and pushing together of braincase and anterior part of skull so much advanced that no evident trace of the primitive postorbital constriction remains visible; parietals not in contact on vertex behind frontals; maxillary never forming part of anterior rim of orbit.

Palatine normal in position, not forming part of anterior wall of slightly backward-sloping narial passage [Relation of maxillary to frontal such that the line of contact between these bones extends upward at a conspicuous angle from the anterior border of the orbit, leaving a broad area of the frontal exposed over middle of orbit when skull is viewed from the side; parietal not visible as a separate element on side of braincase in adult; palatine partly covered by pterygoid, its only surface exposure situated in the normal position on the roof of the mouth; hindermost ribs supported by transverse processes which appear to be not serially homologous with those which support the others; teeth tusk-like in structure].

Facial depression greatly developed, obliterating the longitudinal ridge behind narial orifice; brain relatively small, situated far behind orbit; zygoma complete; (*Physeter* only; exact position of related extinct genera not certain) .... PHYSETERIDÆ.

Facial depression moderately developed, distorting but not obliterating the longitudinal ridge behind narial orifice; brain relatively large, extending forward to level of orbit; zygoma incomplete; (*Kogia* only; exact position of related extinct genera not certain) .... KOGIIDÆ.

Palatine not normal in position, forming part of anterior wall of essentially vertical narial passage.

Anterior teeth single-rooted; posterior teeth double-rooted, their crowns flattened laterally and with serrate margins.. SQUALODONTIDÆ.

Anterior and posterior teeth alike single-rooted, their crowns rarely flattened laterally, and never with serrated margins.

Pterygoids completely covering the palatines on ventral aspect of skull; palatines widely separated from each other and from median line of palate; external reduplication of pterygoid as large as original plate and closely simulating the original plate in form (*Platanista* only) .... PLATANISTIDÆ.

Pterygoids not completely covering the palatines on ventral aspect of skull; palatines in contact or virtually so in median line of palate; external reduplication of pterygoid, when present, never as large as the original plate and never closely simulating the original plate in form ; [Relation of maxillary to frontal such that the line of contact between these bones extends backward in a nearly horizontal direction over the entire orbit, leaving no broad area of the frontal exposed over middle of orbit when skull is viewed from the side].

Maxillary with a freely projecting plate-like process extending backward toward squamosal; pterygoid without reduplication either external or internal........INIIDÆ.

Maxillary with no backward-extending plate-like process; pterygoid with reduplication, either external or internal or both.

Pterygoid greatly enlarged [covering alisphenoid], the area of its outer side equal to that of base of braincase [its reduplications low and ridge-like]; teeth of adult reduced to one or two in lower jaw, absent in upper jaw; rostrum deepened and solidified; hindermost ribs supported by transverse processes which appear to be not serially homologous with those which support the others..............ZIPHIIDÆ.

Pterygoid not enlarged, the area of its outer side less than that of base of braincase; teeth of adult not reduced to one or two in lower jaw, normally present in upper jaw; rostrum not deepened and solidified; hindermost ribs (except possibly in some extinct genera) supported by transverse processes which appear to be serially homologous with those which support the others.................DELPHINIDÆ.

Alisphenoid not overspread by pterygoid; internal reduplication of pterygoid present, usually well developed; no external reduplication.

Teeth not tusk-like in manner of growth; dentition never reduced to a single forward-projecting tusk.

Intermaxillary never extending conspicuously forward beyond maxillary. *Delphininæ.*

Intermaxillary said to extend conspicuously forward beyond maxillary. *Eurhinodelphininæ.*

Teeth tusk-like in manner of growth; dentition reduced to a single forward projecting tusk, usually present in one maxilla of male only ....*Monodontinæ.*

Alisphenoid overspread by pterygoid; both internal and external reduplications of pterygoid normally present.

Pterygoid with reduplications large; teeth of normal delphinine type.......*Stenodelphininæ.*

Pterygoid with reduplications small; teeth tusk-like in manner of growth.*Delphinapterinæ.*

BEHAVIOR OF THE MODERN CETACEAN SKULL

Having now reviewed the details of the results accomplished by the process of telescoping it becomes possible to conjecture something as to the probable behavior of the skull while undergoing its modifications. Telescoping of the braincase and basining of the forehead appear to have been mechanical necessities in the development of the modern cetacean skull. These processes have followed two courses, which may be most readily understood by examining the structure of the proximal portion of the maxillary bone (pp. 9-10, pls. 3-4). In the baleen whales the maxillary is seen to have retained the orbital portion of its body, while the ascending process has interlocked with the body of the frontal. Basining appears thus to have been interfered with, and telescoping appears to have been made less feasible from before than from behind. In the toothed cetacea the maxillary has lost the orbital portion of its body, while the ascending process has slipped freely over almost the entire frontal. Basining seems thus to have been favored, and telescoping from the front seems to have been rendered more feasible than telescoping from the rear. The opposite interpretation should be considered, namely, that the orbital portion of the maxillary might have been destroyed in the toothed cetacea by an especially strong tendency to basining in the members of this group, arising, perhaps, in connection with the development of the facial fat mass, and that in the baleen whales the orbital portion might have been permitted to remain, partly because the facial fat mass did not develop, and partly because the tendency toward telescoping from behind was for some unknown reason more pronounced than that toward modification from in front. While it is probably true that the mechanical forces to which the skull has been subjected have not been exactly alike in the members of the two groups, such differences as can be discovered do not appear to be sufficient, either in degree or in kind, to have been solely responsible for marking out and maintaining two entirely distinct courses of modification. Furthermore we find that the orbital portion of the maxillary is as completely absent in those toothed cetaceans whose skulls are practically not basined at all (*Stenodelphis*, for instance, pl. 7, fig. 2) as it is in those which show the basining process highly developed (*Mesoplodon*, pl. 5, fig. 5 ; *Physeter*, pl. 6, fig. 1 ; *Kogia*, pl. 7, fig. 3; *Hyperoodon*, pl. 7, fig. 4).

Whatever the true history may prove to have been, when revealed by the discovery of fossils now unknown, it is safe to say that throughout the course of remodeling the skull seems to have behaved, in the main, as if it had consisted of three loosely joined masses of plastic material arranged serially and acted upon by two opposing, compressing, forces. One of these forces would have pushed forward from behind, the other would have resisted or pushed backward from in front, with the result that forward motion was established in the posterior mass and backward motion was established in the anterior mass, these two masses acting at the expense of the one which lay between them, covering it, eating into it, and finally obliterating a great part of it (compare the large frontal and parietal in a normal skull, pl. 7, fig. 1, with the completely eliminated parietal and excessively modified frontal in *Kogia,* pl. 7, fig. 3). Of the three masses the anterior would be represented by the rostrum, the posterior by the occipitals and squamosal, the intermediate by the frontal, parietal and sphenoids. While motion of the cranial elements has occurred in every known modern cetacean the dominant direction of this motion has not always been the same; sometimes it has been chiefly a forward thrust of the posterior elements (pl 1, fig. 2; pl. 6, fig. 4), sometimes most conspicuously a backward thrust of the anterior elements (pl. 1, fig. 1; pl. 7, fig. 2), occasionally a less one-sided combination of the two thrusts (pl. 7, fig. 3; pl. 8, figs. 3, 4). The causes which actually determined these differences in the motions of the various bones are now unknown; but the special peculiarities in the behavior of the moving cranial elements in each of the two main types seem to have been predominantly such as might be imagined to have resulted from the encountering of definite mechanical obstacles, varying in their degree of efficiency, lying some of them in the region of juncture between the occipital and the parietal, others in that between the maxillary and the frontal.

The possible character of the obstructions to the telescoping process, and the reason why these obstructions, instead of being uniform in all cetaceans, were more effective checks to movement at one point in the mysticetes and at another in the odontocetes, can be surmised from the rather unexpectedly conspicuous differences which have been found to exist in the details of the devices by which the bones of the skull are interlocked in mammals whose heads have not been subjected to compression (pp. 5-6; pls. 2-3). As to the nature of the compressing forces: the one acting from behind would probably be represented mostly by the mere forward push of the rapidly swimming body; that acting from the front would be the resistance of the water. In the toothed cetaceans the modifications seem to have proceeded as though influenced by forces which were relatively simple in both directions. In the baleen whales, on the contrary, the opposing forces may have been more complex. They perhaps might be analyzed as follows: (1) From in front; (a) the resistance of the water through which the animal moved, (b) the constant downward pull exercised by the increased weight of the rostrum and jaws consequent on their enlargement as the framework of the food-straining apparatus, and (c) the very unusual downward pull which must occur when the animal in feeding swims forward with the lower jaw lowered and the under part of the mouth distended by the enormous quantities of water taken in for straining through the baleen plates: (2) From behind; (a) the forward push of swimming, and (b) the upward pull needed to counteract 1b and 1c. The presence of some special downward-pulling force seems to be required as part of the explanation of the great forward extension of the upper margin of the occipital shield which has been one of the noticeable features in the developmental history of the baleen whale group. This oblique extension of the shield gives increased area for the insertion of the muscles which hold the head in its horizontal position, and at the same time it gives increased length to the power arm of the lever by which any downward force applied to the anterior part of the head is opposed. An analogous mechanical problem has been solved by a parallel though much less extreme modification of the skull in some of the burrowing rodents, particularly in those which have not developed specially enlarged fore feet. Such animals make free use of the teeth and snout in digging; consequently the fore part of the skull must be pressed upward against the soil through which a passage is being made. This active upward-forcing of the rostrum against a resistant medium appears to have brought into play the same muscles that would be required for maintaining the horizontal position of the fore-weighted head of a baleen whale. It is therefore not surprising to find that a distinct parallelism should be present between the vertical portion of the skulls of such widely unrelated mammals as *Rhachianectes* and *Spalax*. In the rodent (pl. 8, fig. 8) the occipital shield has extended far enough forward over the parietals to reduce their exposed portion to small elements, while in the whale (pl. 8, fig. 3) it has obliterated the parietals on the vertex and has continued forward beyond them far enough to reduce the frontals in their turn to elements whose size relatively to the neighboring structures is not greatly unlike the exposed area of the parietals of the rodent.[1] The fact that the modification has gone farther in whales than in rodents may perhaps be not entirely unrelated to the circumstances that the muscular activity in the one instance is needed during the act of burrowing only, while in the other it is needed at its maximum whenever the animal feeds; and the part of it which is required to oppose gravitation must be continuous from birth to death. An additional reason to believe that the forward extension of the frontal shield in the baleen whales may be in part related to the great development and peculiar function of the rostrum and jaws is furnished by the fact that this extension is in general more pronounced throughout the mysticete group than it is in the toothed cetacea. Among the latter there is no enlarging of the mouth to engulf great quantities of water; the combined weight of the rostrum and jaws is almost without exception much less, relatively to the weight of the cranium, than it is in the mysticetes; and in no dolphin or toothed whale, no matter what the degree or kind of telescoping, even in such excessively compressed types as *Hyperoodon* and *Kogia* (pl. 7), does the occipital shield increase its area by pushing obliquely forward noticeably beyond the level of the articular region, a level which it normally passes in all of the more specialized baleen whales. (Compare *Stenodelphis*, pl. 7, fig. 2, a dolphin with greatly elongated rostrum, and *Eubalæna*, pl. 6, fig. 4, a member of the other group; in the former the anterior border of the occipital lies slightly behind the articular level while in the latter it lies far in front; the articular area in each is situated below the reference letters *sq*, and the position of the anterior edge of the occipital is marked by the sign +.)

The probability that water pressure has been one of the main factors in determining the behavior of the modern cetacean skull seems to be much strengthened by an examination of the characters of the two other groups of mammals whose members have assumed an exclusively aquatic mode of existence. These groups are the zeuglodonts and the sea-cows. In the former the skull has retained most of its generalized mammalian structure, in the latter it has

[1] A definite overlapping of the hinder border of the parietal by the occipital occurs in the pigs and peccaries, both of which use the snout for "rooting" in an upward direction; but the process in these animals differs from that which is seen in the baleen whales and *Spalax* in that it takes place in a nearly vertical direction so that the occipital shield faces backward on the occipital aspect of the skull. It appears to be associated with a pushing forward of the base of the braincase which would indicate the action of some remodeling force which does not operate in the whales and rodents.

departed widely from this primitive type; but in neither is there any telescoping: the bones unite with each other in the normal way. Both zeuglodonts and sea-cows are contrasted with modern cetacea in three peculiarities which must be directly related to the mechanical pressures which are brought to bear on the skull. These are: (a) Smaller size of the head in proportion to that of the body, (b) greater length of the neck in relation to that of the head, and (c) distinctly less enlargement of the vertebral processes which serve as areas of attachment for the muscles that operate the caudal propellor. It seems obvious therefore that the head, in these aquatic mammals with non-telescoped skulls, has been subjected to a less violent conflict with the water than that of the modern cetaceans, because (a) its area opposed to the water in the act of swimming is less, (b) it is not held so stiffly and uniformly pressed into the resisting element, and (c) it is driven against the water at a lower speed. This last factor is probably the most important of the three. The resistance which water presents to a moving body increases as the square of the velocity. Hence if a porpoise swims twice or three times as fast as a sea-cow its head will be subjected to from four to nine times the backward pressure encountered by the head of the less rapidly moving animal.

Cetaceans, as is well known, are born in the water. The young must therefore acquire the ability to swim rapidly at an early age. Exactly how soon they gain the power of freely accompanying the adults cannot be stated with any degree of certainty; but there can be no doubt that the habit of rapid swimming is established long before the skull has reached its full growth. The peculiar behavior of the modern cetacean skull may therefore, as it seems, not impossibly be connected with this fact: that during much of that critical period in which the skull of an ordinary land mammal is rapidly and, so to speak, peacefully accomplishing its process of loose-jointed growth the skull of a young cetacean is fighting its way to adult stature against the two opposing forces of body push from behind and water resistance from in front.

It may be possible to form a better understanding of the subject of behavior when a considerable number of cetacean embryos representing the earliest stages of growth of the principal bones of the skull can be examined. Unfortunately I have not had access to such material, and I have found very scant published information which bears directly on the problem in question. As regards the odontocetes there appears to be little or nothing on record concerning the stages intervening between the formation of the chondrocranium and the essentially final structure of the skull. Early conditions in two of the mysticetes were figured many years ago by Eschricht in his well-known accounts of *Balæna mysticetus* and *Balænoptera acutorostrata;* recent contributions to the subject have been made by Schulte (Mem. Am. Mus. Nat. Hist., n. s., Vol. I, pls. 54-56, 1916; *Balænoptera borealis*) and Ridewood (Phil. Trans. Roy. Soc. London, ser. B, Vol. 211, pp. 209-272, May 8, 1922; *Megaptera* and *Balænoptera*). In the absence of more complete information I shall not attempt any discussion of the evidence furnished by the structure found in embryos.

REMARKS ON THE CLASSIFICATION HERE ADOPTED

The classification of the cetacea to which the present study of telescoping has led is as follows:

Order Cetacea.
- Suborder ARCHÆOCETI (= Series I).
  - Family *Protocetidæ* (*Protocetus*).
  - Family *Dorudontidæ* ("Zeuglodon" with short vertebræ).
  - Family *Basilosauridæ* (*Basilosaurus*).
- Suborder MYSTICETI (= Series II).
  - Family *Balænidæ* (*Balæna, Eubalæna*).
  - Family *Neobalænidæ* (*Neobalæna*).
  - Family *Cetotheriidæ* (*Cetotherium* and allied extinct genera).
  - Family *Rhachianectidæ* (*Rhachianectes*).
  - Family *Balænopteridæ*.
    - Subfamily *Megapterinæ* (*Megaptera*).
    - Subfamily *Balænopterinæ* (*Balænoptera, Sibbaldus*).
- Suborder ODONTOCETI (= Series III).
  - Family *Agorophiidæ* (*Agorophius, Archæodelphis, Xenorophus;* perhaps *Patriocetus*).
  - Family *Physeteridæ* (*Physeter;* position of extinct related genera uncertain).
  - Family *Kogiidæ* (*Kogia;* position of extinct related genera uncertain).
  - Family *Squalodontidæ* (*Squalodon; Prosqualodon ?*).
  - Family *Iniidæ* (*Inia, Lipotes,* and several extinct South American genera).
  - Family *Delphinidæ*.
    - Subfamily *Delphininæ* (The typical dolphins).
    - Subfamily *Eurhinodelphininæ* (*Eurhinodelphis* if correctly described).
    - Subfamily *Stenodelphininæ* (*Stenodelphis, Palæopontoporia;* perhaps *Argyrocetus*).
    - Subfamily *Delphinapterinæ* (*Delphinapterus* only).
    - Subfamily *Monodontinæ* (*Monodon* only).
  - Family *Ziphiidæ* (The beaked whales).
  - Family *Platanistidæ* (*Platanista* only).

It will be seen that this arrangement of the order does not differ materially from those which have been most generally in use (for a summary of the principal attempts at classifying the cetaceans see Winge, Smithsonian Misc. Coll., Vol. 72, No. 8, pp. 58-62) except in the greater independence now attributed to all three of the suborders, and, among the members of the Odontoceti, in the wide separation of the ziphiids from the physeteroids, and especially in the separation of the rather primitive iniids from *Platanista,* the genus which I regard as presenting the greatest total of modifications known in any cetacean. Aside from these admittedly controversial details the departures from accepted usage, so far as such usage can be said to exist, chiefly pertain to questions of judgment with regard to the limits of the minor groups and the relative importance assigned to some of these groups. That a classification based on a mostly untried set of characters should coincide in the main with the classifications already in existence indicates the general soundness of the broader results of work on cetacean taxonomy. The differences in detail are mostly the result of two causes: first, that some of the characters hitherto regarded as indices to relationship now appear to be parallel and independent modifications, and, second, that comparatively few of the extinct members of the order are known from remains complete enough to show the features which are now seen to be needed for a natural classification. Examples of the first are furnished by the beak form supposed to bring together the otherwise excessively different *Platanista* and *Inia* or *Lipotes;* the tusk-like tooth structure supposed to indicate relationship to the sperm whales on the part of various fossil cetaceans known from teeth only (this structure now appears to be merely a mechanical strengthening of the teeth by means which have been independently adopted in the sperm whale, the white whale and the ziphiids; probably elsewhere under the influence of appropriate stimulus); the unusual relationship of the hindermost ribs to the vertebræ supposed to be evidence in favor of placing the ziphiids in the same group with the sperm whale notwithstanding the fundamental differences presented by the structure of the skulls. Examples of the second are so numerous that detailed listing is scarcely necessary in the present connection. A few characteristic instances are furnished by the remains which formed the bases of the following 30 generic names: *Agriocetus, Cetophis, Cetorhynchus, Delphinavus, Delphinopsis, Dinoziphius, Eucetus, Hesperocetus, Hoplocetus, Iniopsis, Ixacanthus, Kekenodon, Metasqualodon, Microcetus, Microzeuglodon, Ontocetus, Orycetero-*

cetus, Palæodelphis, Patriocetus, Phocænopsis, Phocagenius, Physodon, Priscodelphinus, Prophyseter, Prosqualodon, Protophocæna, Rhabdosteus, Scaldicetus, Stenodon, Tretosphys.

Most of the supergeneric groups here recognized have already been sufficiently discussed for the purposes of this paper. Concerning some of them further observations may not be out of place.

Archæoceti.—Cabrera (Manual de Mastozoología, p. 316, 1922) has recently placed the zeuglodonts in an order separate from the modern cetacea. This may be the first step toward the eventual elevation of all three of the currently recognized major groups to the rank of orders.

According to Pompeckj (Senckenbergiana, Vol. 4, pp. 43-100, October 20, 1922) the structure of the periotic bone in the zeuglodonts resembles that now found in the baleen whales. The presence of such conditions is not likely to mean anything more than a parallel development of the ear in the two groups, or more probably, the existence of similar ear structure in the two ancestral stocks from which these groups took their origin. The difficulties in the way of deriving a mysticete skull from one which had first assumed the form present in all known zeuglodonts appear to be little short of insuperable.

Agorophiidæ.—The three American genera now placed in this family are well differentiated from each other though they probably represent one stage of the telescoping process. Whether the genus *Patriocetus* belongs in the same family or whether it represents a distinct group are questions which the descriptions and figures do not furnish the data for answering. The photographs published by Abel (Denkschr. kais. Akad. Wissensch. Wien, math.-naturw. Kl., Vol. 90, pls. 1-4, 1914) indicate (a) that the general form of the skull in both dorsal and lateral view is essentially like that of *Agorophius* (Smithsonian Inst., Special Publ., No. 1694, pl. 6, 1907), and *Archæodelphis* (Bull. Mus. Comp. Zool., Vol. 65, No. 1, figs. 1, 2 and plate, 1921), (b) that the braincase is similarly small as compared with the rest of the skull, and (c) that a deep postorbital constriction is present. Apparently the maxillary may have formed part of the anterior orbital wall as in *Archæodelphis.* The most obvious difference from *Agorophius* clearly shown by Abel's photographs is the presence of a thin overhanging ledge sloping upward and backward from the hinder margin of the orbit, and partly obscuring the postorbital constriction. The surface of the fossil is thickly covered with grains of sand which obscure most of the finer details. (See remarks by König, Jahres-Ber. Mus. Franc.-Carol., Linz, Vol. 69, p. 111, 1911.) Such details as can be seen are, however, in accord with the conditions present in both the kind and stage of telescoping represented by *Agorophius* and *Archæodelphis.* The reconstructions given by Abel in plates 6 and 11 show, on the contrary, a structure which differs fundamentally from that known to occur in any other cetacean. The maxillary is represented as broadly united with the frontal by a straight suture extending directly inward to the intermaxillary from a point situated on the side of the rostrum in front of the anterior margin of the orbit. No part of the maxillary extends behind this level either above or below the frontal; yet the intermaxillary runs far back behind both maxillary and orbit, its extremity touching the parietal. The fronto-maxillary suture, if correctly interpreted, is not very different from that usually seen in the zeuglodonts. The relative degree of backward extension of the maxillary and intermaxillary is, on the contrary, something unknown either in zeuglodonts or in cetaceans with telescoped skulls. It should further be noticed that essentially normal conditions, not very different from those which appear to have been present in *Agorophius* were described by König as occurring in the specimen afterward interpreted by Abel. In the zeuglodonts the relationships of these two bones have remained normal, and the posterior border of the maxillary lies behind the extremity of the intermaxillary (pl. 5, fig. 1). During the process of telescoping in all known cetaceans it appears to be the maxillary which leads in the backward move, so that in rare instances only does the intermaxillary attain the more posterior level, and then by such a mere trifle as to form no real exception to the general rule (see diagram of *Rhachianectes,* pl. 8, fig. 3). That the intermaxillary in any cetacean should have extended backward to the parietal while the maxillary remained stationary in front of the orbit is so contrary to probability that the evidence of an unusually well preserved specimen would be necessary before anything of the kind could be believed to have taken place. If such a condition should ever be demonstrated to occur it would indicate the existence of a third type of telescoping not directly related to or derivable from either of those now known. That the genus *Patriocetus* as interpreted by Abel would be unlikely to represent a stage ancestral to the modern baleen whales appears to be clearly enough indicated by the character just mentioned; it is made practically certain by the absence of the orbital plate of the maxillary, no trace of which appears either in Abel's photographs or restoration (based chiefly on the second specimen), or in Van Beneden's drawing of the original type skull. The absence of the plate, which seems to be real and not due to mutilation of the fossils, is an indication that *Patriocetus* belongs definitely among the toothed cetaceans; as it is probable that in any form actually preceding the modern baleen whales the plate would necessarily be present, and its size would with little doubt be relatively greater than in existing members of the group.

Physeteridæ.—The family *Physeteridæ* is not definitely known to be represented by more than two genera, the living *Physeter* and the Miocene "*Paracetus*" of Cope. Its characters consist primarily of a combination of telescoping-type, development of the facial depression, structure of the zygomatic arch, palatine and pterygoid, and the relation of the posterior ribs to the vertebræ; features which are not commonly preserved in fossils, but without a knowledge of which no positive classification of a cetacean genus is possible. The palatine bone retains its horizontal position in the roof of the mouth. It is overridden from behind by the pterygoid; but the general relationships of the two bones to the neighboring cranial elements is otherwise so normal that the conditions present in *Physeter* can readily be explained as the result of simple telescoping of elements originally in about the same relative positions as those in ordinary carnivores. While the narial passage shows a distinct trace of the primitive backward slant it is situated mostly behind the level of the orbit. There is no longitudinal median ridge on the forehead behind the narial aperture. The posterior orifice of the infraorbital canal is formed by the maxillary and lacrimal, the relationship of these two bones, so far as the orifice of the canal is concerned, being not very different from that which exists in the fox (pl. 3, figs. 4 and 5). Atlas distinct, the other cervical vertebræ fused with each other and with the first dorsal, a combination of relationships unknown in the cervicals of any other cetacean. Among the insufficiently known extinct cetaceans the genus *Thalassocetus* appears to be the one which is most probably a member of the physeterine group. Its frontal and maxillary are figured as not widely unlike those of *Physeter,* but the remains are very fragmentary. The possibility that *Diaphorocetus* ("*Hypocetus*") may belong in the same group must also be considered. On the other hand *Physeterula* is more likely to be a delphinid with the orbital edge of the frontal thickened in a manner that is unusual though not unknown among the dolphins; and the *Physodon patagonicus* of Lydekker, as described and figured, can with equal probability be referred to the *Delphinidæ.* In this animal the structure of the orbit and of the maxillary above and behind the orbit differs in no essential feature, so far as can be judged from the plate representing the lateral aspect of the skull, from the conditions present in *Globicephala;* on the other hand the positions of the foramina near the orbit as figured from in front suggest those in the type specimen of Cope's "*Paracetus*" *mediatlanticus.* The names *Eudelphis* and *Homœocetus* were based on vertebræ resembling the peculiar atlas of the sperm whale. It is therefore not impossible that they refer to members of the family *Physeteridæ.* Various names of supposed physeteroids, such as *Balænodon, Eucetus, Hoplocetus, Palæocetus, Physetodon,* have been applied to isolated teeth. Some of these teeth as described and figured are of the same tusk-like type as those of the sperm whale. Others resemble the enlarged teeth of such delphinids as *Orcinus* and *Pseudorca,* in which the growth is not tusk-like, the portion below the well-defined, enamel-covered crown being merely enlarged and thickened, but with a closed base. The systematic position of the animals which bore these teeth is conjectural. Though nothing of the kind is yet known it does not seem impossible that a physeteroid might have teeth of the *Orcinus* type; while the inconclusiveness of the evidence furnished by isolated tusk-like teeth is shown by the fact that this kind of tooth growth occurs not only in the sperm whale and *Kogia,* but also in the beaked whales, the narwhal and the white whale. Although in appearance extremely specialized, chiefly on account of the unusual basining of the facial region, the skull of *Physeter* is, like that of *Kogia,* more primitive in its ground plan, as shown by the structure of the narial passage, the palatine and the pterygoid, than that of any other known toothed cetaceans except the agorophiids.

Kogiidæ.—While the living genus *Kogia* agrees with *Physeter* in general structure it differs so much in details that it probably represents a special family. The discovery of fossil forms may, however, eventually result in obscuring the apparent distinctness of the two groups. The more important of the details which, taken together, now seem of family value are: the fusion of all the cervical vertebræ into a single mass distinct from the first dorsal as in the ziphiids and the typical dolphins; the situation of the orbit at a level mostly behind that of the narial passage; the presence on the forehead of a distorted but evident longitudinal median ridge extending backward from the narial orifice; the fusion of the jugal and lacrimal into a mass lying entirely anterior to the orbit and having a superficial exposure nearly equal to that of the frontal. No fossil representative of the family

Kogiidæ has yet been identified. Cope supposed that his "*Paracetus*" *mediatlanticus* from the Upper Miocene of Maryland was related to *Kogia;* but an examination of the original specimen shows that it really belongs near *Physeter.* The tooth on which Leidy based the name *Orycterocetus* may have come from a cetacean not unlike *Kogia,* and the same is true of some teeth of a supposed physeterid figured but not named by Abel (Mém. Mus. roy. Hist. Nat. Belgique, Vol. 3, p. 74, figs. 9 and 10, 1905) from the Antwerp Crag.

Squalodontidæ.—Chiefly on account of their peculiar teeth the squalodonts are usually regarded as constituting a special family. In this position they may be allowed to remain, though it must be observed that their distinctness from the living *Iniidæ* (*Inia* and *Lipotes*) does not rest at present on characters that are very satisfactory or very well understood. The telescoping of the braincase is of the same kind and degree as in the existing iniids, and the frontal appears to share to the same extent in the formation of the lateral wall of the braincase; the orbit, as in the living animals, is situated a little in front of the level of the narial passages. The ethmoid is less reduced than in existing iniids. I have not seen a specimen of *Squalodon,* nor can I find one described, in which the structure of either the palatine, the pterygoid, or the basal portion of the maxillary is sufficiently well preserved to show the characters needed for definite classification; but there is apparently nothing known about the fossils to prove that the conditions as regards these very important elements of the skull differed from that which is now found in the iniids. The peculiarities of the squalodont dentition, however, especially the tendency of the posterior teeth to assume a conspicuously trenchant character appears to indicate a line of development which was not leading directly toward any of the existing groups of porpoises.

The genus *Prosqualodon* as described and figured by Lydekker would appear to be a member of this family. As restored by Abel, however (Sitzungsber. k. Akad. Wissensch. Wien, Math-naturwiss. Kl., Vol. 121, pp. 57-75, pls. 1-3, 1912), the skull is, in important features, intermediate between that of *Squalodon* and that of *Agorophius.* Abel describes the parietals as forming a broad band across the vertex between the frontals and the occipital shield, a condition not mentioned by Lydekker and not shown in his figure of the type or of the specimen in London afterward studied by Abel. Such a character, if verified, would show the presence of a stage of telescoping decidedly anterior to that present in *Squalodon,* and would place the genus *Prosqualodon* in a family of its own.

Iniidæ.—There has been much difference of opinion as to the systematic position of *Inia* and its allies, though they have, perhaps, been most frequently united with *Platanista* and *Stenodelphis* to form a special family. The unnaturalness of this grouping has been recognized by Abel, True and Rovereto. The genus *Platanista* is widely separated from the others by the physeteroid character of its telescoping (compare pl. 6, fig. 2, with pl. 7, fig. 2) and by the excessively specialized structure of its palatine and pterygoid. The South American *Stenodelphis,* though less distinct from the iniids than from *Platanista,* is definitely separated from both *Inia* and *Lipotes* by the structure of its palate (it agrees with them in type of telescoping). This leaves these two existing genera and their extinct allies to stand alone. Considered as a group they resemble the *Delphinidæ* in the type of telescoping and in some other characters of the skull. The braincase, however, has not attained its extreme size, and has not encroached on the temporal fossa so much as in the typical modern dolphins, peculiarities which suggest the squalodonts. A character which might be interpreted as vaguely squalodont is also indicated by the tendency of the posterior teeth to differ in form from those at the anterior end of the series; but the broadened teeth of *Inia* obviously resemble the tuberculate teeth of *Delphinodon* rather than the narrow trenchant posterior teeth of *Squalodon.* The structure of the palate is less specialized than in any of the known toothed cetacea except the physeteroids and agorophiids. (The more important characters of the palate in the squalodonts, it must be remembered, are not known.) The narial passage has become perpendicular, and the palatine bone has lost its primitive position on the roof of the palate; the orbits are situated in front of the level of the nares; narial process of palatine well developed and forming an important part of the anterior wall of the narial passage. Pterygoid simple, not spreading laterally over alisphenoid, and not reduplicated along either margin. Posterior orifice of infraorbital canal apparently formed by maxillary alone. A peculiar specialization is seen in the presence of a narrow, freely projecting plate given off by the posterior extremity of the maxillary and extending back nearly to the squamosal in somewhat the same position as that which is occupied by the outer reduplication of the pterygoid in such delphinids as *Delphinapterus* and *Stenodelphis.* In addition to the living genera *Inia* and *Lipotes,* I would regard as probably members of this group the fossils which have formed the bases of the following names: *Anisodelphis, Argyrocetus* (perhaps better referred to the *Stenodelphininæ*), *Ischyrorhyn-*

chus, Pontivaga, Pontoplanodes, Proinia. No extinct porpoise referable with any high degree of probability to the family has yet been found outside of South America. The living *Lipotes* of China is the only cetacean, recent or fossil, definitely known to represent the group in the Northern Hemisphere or in the Old World. Various extinct European genera, such as *Champsodelphis, Cyrtodelphis,* and *Acrodelphis* have been supposed to be related to *Inia,* chiefly because of the presence of a deep longitudinal groove on each side of the under surface of the mandible. While some of these porpoises may eventually prove to be iniids it must be remembered that the development of grooves, in both mandible and beak, appears to be merely a general though not universal tendency in dolphins with slender rostrum and long symphysis. Among living forms this grooving tendency is best developed in *Stenodelphis.* Its next degree is found in the distantly related *Platanista.* In *Lipotes* and *Inia* it is very slightly indicated, though these genera are more nearly related to *Stenodelphis* than any of the three is to *Platanista.* By itself, therefore, this feature is not an index to affinity. The presence of *Lipotes* in the Old World makes the eventual discovery of extinct members of the subfamily appear certain; but their positive identification will depend on the finding of material sufficiently well preserved to show the true structure of the pterygoid and maxillary as well as the size of the temporal fossa and the extent to which the frontal participates in forming the lateral wall of the braincase.

Delphininæ.—After removal of *Inia* and *Lipotes* as a family, and of *Stenodelphis, Delphinapterus, Monodon,* and, provisionally, *Eurhinodelphis,* as the representatives of four subfamilies, the dolphins become a rather compact group chiefly characterized by the high degree of telescoping of the braincase, the small temporal fossa, the small pterygoid reduplicated on its inner side only, and not spreading over the alisphenoid; teeth normally-growing (never tusk-like); posterior orifice of antorbital canal usually formed by maxillary alone, though sometimes (*Lissodelphis, Neophocæna*) its lower edge is narrowly touched by the palatine. The orbits are situated so far posteriorly as to lie in the same transverse plane as the narial passages. Since the narial passages have been moved as far back as the brain will allow, it seems at first sight as though the equally posterior position of the orbits might be regarded as a feature of high specialization in comparison with the more anterior position which they occupy in *Monodon, Delphinapterus,* the iniids, and even more conspicuously in *Platanista,* a position which appears to be less of a departure from the condition found in ordinary mammals. That such may not be the case, however, is indicated by the fact that the posterior opening of the antorbital canal lies under the anterior border of the orbit in the *Delphininæ* in a position (pl. 1, fig. 1*a*, *a. o. for.*) essentially the same as that which may be seen in a sea-lion (pl. 2, fig. 2*a*, *a. o. for.*), while in the skulls with more anteriorly placed orbit the orifice of the canal usually though not always lies behind the position which it normally occupies with regard to the orbit. This would appear to show that a readjustment of parts had taken place (most conspicuous in *Platanista*), a process representing a higher degree of specialization than that indicated by a greater pushing backward of the orbit without readjustment of relative positions. The form of the rostrum is variable and of little importance for distinguishing groups higher than genera. This typical subfamily includes the great majority of both living and fossil members of the family. The recent genera are so well understood that they do not require special mention here. Among the fossils which I would refer without too great hesitation to the *Delphininæ* as thus restricted are those which have formed the bases of the following generic names: *Acrodelphis, Champsodelphis, Delphinodon* (as understood by True, Proc. Biol. Soc. Washington, Vol. 24, pp. 37-38, February 24, 1911; crowns of posterior teeth with a broadened inner portion suggesting that which occurs in the living *Inia.*), *Heterodelphis, Lophocetus, Palæophocæna, Palæoziphius, Physeterula, Physodon* of Lydekker 1893 (probably not of Gervais 1872), *Pithanodelphis, Pomatodelphis* (may be referable to the *Iniidæ*). Others which may belong here are: *Cetorhynchus, Delphinavus, Delphinopsis, Dinoziphius* (teeth suggesting those of a very large *Orcinus*), *Hesperocetus, Iniopsis, Ixacanthus, Phocænopsis, Priscodelphinus, Protophocæna.* The names in this second list are, however, based on such fragmentary material that no clear idea can at present be formed regarding the animals to which they are applied.

Eurhinodelphininæ.—The genus *Eurhinodelphis* has been placed in a special group, principally on account of the supposed forward extension of the intermaxillary in front of the maxillary to form the entire anterior third of the greatly elongated beak. In other respects there appear to be few highly exceptional peculiarities to separate the genus from ordinary delphinids. While such a development of the intermaxillary would undoubtedly be reason for regarding the animal as the representative of a distinct subfamily the evidence for its occurrence is inconclusive. Mr. Remington Kellogg has called my attention to the fact that there is no reason to regard the structure of the rostrum in *Eurhinodelphis* as different from that in any other long-beaked porpoise, at least so far as regards the specimen collected by True near Chesapeake Beach, Maryland, and briefly recorded in 1908 (Proc. Amer. Philos. Soc., Vol. 47, p. 388). This skull (No. 10,464, U. S. National Museum), well preserved except for the base and sides of the braincase, agrees in all essential respects with Abel's figures (Mém. Mus. roy. Hist. Nat. Belgique, Vol. 1, pls. 6-8, 1901) of the European animal. The structure of the rostrum is not very different from that of the rostrum of *Stenodelphis*. As is commonly the case in long-beaked dolphins the boundaries between the maxillary and intermaxillary bones are obliterated. Obliquely crossing the side of the rostrum, from the main lateral sulcus to the alveolar level, in the position marked by the white suture line in Abel's plates there occurs a faint groove about 3 mm. wide and so shallow as to be almost invisible in unfavorable light. It appears to indicate the course of some nerve or blood vessel that ran forward and downward along the surface of the maxillary from the lateral sulcus to the anterior part of the roof of the mouth. There is nothing in the appearance of this shallow, wide groove that suggests the narrow, smooth suture which joins the maxillary and intermaxillary in the skulls of porpoises which retain traces of this juncture. If the characters of the European specimens are no more unusual than those of this Maryland skull there would appear to be no grounds for regarding *Eurhinodelphis* as the representative of a distinct group.

Stenodelphininæ.—The genus *Stenodelphis* has been placed in the *Delphinidæ*, the "*Platanistidæ*" and the *Iniidæ*. The position which it seems to occupy most naturally is that of a subfamily in the family *Delphinidæ*. With it should be associated the extinct *Palæopontoporia* and perhaps *Argyrocetus*. The characters of the group are to be found in the structure of the braincase, the temporal fossa, and the pterygoid, not in the elongated beak. The pterygoid is widely spread over the surface of the alisphenoid, completely covering this bone and coming into broad contact with the frontal as in *Delphinapterus*. The external reduplication of the pterygoid is like that of *Delphinapterus*, but even better developed; the internal reduplication is large and apparently of the same type as in the true dolphins, but the only specimen which I have examined is not in entirely satisfactory condition. Orbits relatively smaller than in the *Delphininæ*, their position immediately in front of the transverse plane occupied by the narial passages; these peculiarities agreeing with the conditions present in the iniids, and perhaps representing a structure more primitive than that now existing in the true dolphins. Posterior orifice to the infraorbital canal formed by the maxillary alone. Teeth of normal delphinine type, with no tendency toward a tusk-like manner of growth. Cervical vertebræ retaining their primitive condition of separateness. The living genus *Stenodelphis*, with its extinct relatives, appears to represent a well defined group best treated as a subfamily of the *Delphinidæ*. The structure of the pterygoid and the absence of a backwardly projecting maxillary plate at the side of the palate distinguish it sharply from the *Iniidæ* and connect it with the *Delphinidæ* through morphological features similar to those present in the otherwise very different *Delphinapterus*. Its even more fundamental unlikeness to *Platanista* is shown by the strictly delphinine type of telescoping and of pterygoid structure, as well as by the large size of the palatine and the absence of other modifications connected with extreme backward-forcing of the base of the beak.

Delphinapterinæ.—A similarly isolated position as regards the ordinary dolphins is occupied by the genus *Delphinapterus* which shares some of the peculiarities of *Monodon* and some of those of *Stenodelphis*. In contrast with *Monodon*, however, the posterior basal portion of the pterygoid is spread laterally over the alisphenoid, and in most skulls there is an evident outer pterygoid reduplication like that present in *Stenodelphis;* though the teeth are tusk-like in manner of growth the general character of the dentition is normal, with several functional teeth of approximately equal size in each jaw; some of the hindermost teeth, especially in the upper jaw, show a distinct trace of a tricuspid crown structure when unworn (See True, Smithsonian Misc. Coll. Vol. 52, p. 329, April 28, 1909, and Lönnberg, Arkiv. för Zoologi, Vol. 7, pp. 2-4, fig. 1, July 5, 1910.). The cervical vertebræ, as in both *Monodon* and *Stenodelphis*, retain their primitive condition of distinctness, and the orbits are situated at a level in front of that occupied by the nasal passages. These characters, especially those of the teeth, have led Lönnberg to regard the genus as the representative of a distinct family. They appear, however, to be of no more than subfamily value.

Monodontinæ.—The genus *Monodon* has usually been associated with *Delphinapterus*, principally because in these two genera the cervical vertebræ differ from those of most other living dolphins in retaining their primitive separateness. Similarity between the two genera is also shown by the manner of growth of the teeth, by the conspicuous participation of the palatine in the formation of the posterior orifice to the infraorbital canal, and by the situation of the orbits at a level decidedly in front of that of the narial passages. The orifice of the antorbital canal, as in *Delphinapterus,* lies distinctly behind the level of the anterior border of the orbit, a peculiar position as compared with ordinary mammals which would appear to show that special readjustment of the parts has taken place, either through a backward movement of the base of the rostrum which has carried the foramen with it, or by a secondary forward movement of the orbit after conditions had been established resembling those seen in the *Delphininæ.* On the other hand the posterior basal portion of the pterygoid of *Monodon* does not spread laterally over the surface of the alisphenoid in the peculiar manner seen in *Delphinapterus* and *Stenodelphis.* The relations of these two bones are of the ordinary dolphin type (No. 23,455, U. S. National Museum) except that there appears to be more of a tendency for the anterior basal portion of the pterygoid to expand outward in the direction of the optic canal. The anterior reduplication of the pterygoid is narrow and ridge-like, suggesting the conditions which occur in the ziphiids and in *Delphinapterus,* but of a somewhat intermediate character. This combination of peculiarities taken in connection with a form of dental specialization which is unique among known cetacea appears to be sufficient to place the genus *Monodon* in a subfamily of its own.

Ziphiidæ.—The beaked whales have recently been regarded as near relatives of the sperm whales, often as members of the same family, chiefly because of similarities in the tusk-like manner of growth of the teeth and in the relationship of the hindermost ribs to the vertebræ. These characters now appear to be of little weight relatively to the type of skull-telescoping and the structure of the palatine and pterygoid. In these very important morphological features the beaked whales differ completely from the sperm whales and essentially agree with the delphinids. Telescoping is strictly of the delphinine type (see pl. 5, fig. 5, and pl. 7, fig. 4), the maxillary passing back horizontally over the eye even in such an excessively modified skull as that of *Hyperoodon.* Pterygoid greatly enlarged, covering almost the entire surface of the alisphenoid, its inner and outer reduplications present but low and ridge-like. Posterior orifice of infraorbital canal formed by maxillary, palatine, pterygoid and lacrimal, though the maxillary and pterygoid may be excluded (especially in the genus *Berardius*). It seems proper to consider the beaked whales as near relatives of the delphinids, though sufficiently characterized by the peculiarities of the skull, dentition and ribs to form a distinct family. In general they appear to be more specialized than the dolphins; but the area formed by the palatine in the anterior wall of the narial passage as compared with that formed by the maxillary is narrower than in the dolphins, an apparently primitive feature which might indicate that the group originated from dolphin-like animals which were considerably less modified than any now living.

Platanistidæ.—The genus *Platanista* alone represents the family *Platanistidæ*. The type of telescoping shown by its skull is strikingly different from that seen in the recent genera *Inia*, *Lipotes* and *Stenodelphis*, and the fossil *Pontoplanodes* (as shown by Abel's photographs, Sitzungsber. k. Akad. Wissensch. Wien., Math.-Nat. Kl., Vol. 118, pt. 1, pl. facing p. 272, 1909), all of which, at one time or another, have been associated with it. In this character as well as in the anterior position of the orbit relatively to the narial passages it agrees with *Physeter* so far as general structure of the cranium is concerned; merely the lateral portion of the occipital has not advanced so far forward at the expense of the parietal as in the sperm whales. The resemblance of the frontal to that of a young *Physeter* is particularly noticeable (pl. 6, figs. 1, 2). In all other features the skull differs so widely from that of the sperm whale and its allies that the similarities in the type of telescoping cannot be regarded as indications of near relationship. On the contrary, among living odontocetes the total specialization of the skull is least of all in the physeteroids and greatest of all in *Platanista*, thus indicating the widest possible degree of separation between the two groups. Some of the more important of the special characters of the skull which show extreme departure from ordinary mammalian structures are: the great size of the pterygoid which spreads laterally to cover the alisphenoid and interlock with the squamosal and frontal, and which extends so far forward that about half of its area lies in front of the infraorbital foramen, into the formation of whose posterior and superior margins it largely enters; the development of the outer reduplication of the pterygoid as a heavy plate exceeding the original portion of the bone in both size and in density of structure (this plate is not homologous with the ectopterygoid of other mammals, an outgrowth from the alisphenoid which does not occur in modern cetaceans); the greatly reduced condition of the palatine, widely separated from its fellow of the opposite side and completely covered by the pterygoid except where it appears at the surface in the anterior wall of the narial tube; the backward forcing of the base of the rostrum until the infraorbital foramen is brought to a position behind the orbit and wholly beneath the greatly elongated optic canal; the formation of the anterior orifice of the infraorbital canal by the pterygoid, frontal, and maxillary to the exclusion of the palatine and lacrimal.

Genera whose position is not clear.—Several extinct genera which have been carefully described so far as the known material would allow are still too incompletely understood to be assigned to a definite place in the present classification. Some of these have already been mentioned (see especially remarks on the *Agorophiidæ, Physeteridæ, Iniidæ, Delphininæ, Eurhinodelphininæ* and *Stenodelphininæ*). Others whose position is still more doubtful are those which have been described under the names *Cyrtodelphis, Diochoticus, Eoplatanista,* and *Squalodelphis;* also a remarkably long-beaked dolphin from the Calvert formation of Maryland, an account of which, by Mr. Remington Kellogg, is now in press.

EXPLANATION OF PLATES

In order to eliminate so far as possible the confusing influence of the great differences in size presented by the skulls of such animals as foxes, porpoises and baleen whales, most of the specimens have been photographed at a length of about 7-8 inches and then reduced to the dimensions required by the plates. Any attempt to indicate the scales of the various reductions would be contrary to the strictly morphological purposes of the illustrations.

The following abbreviations are used:

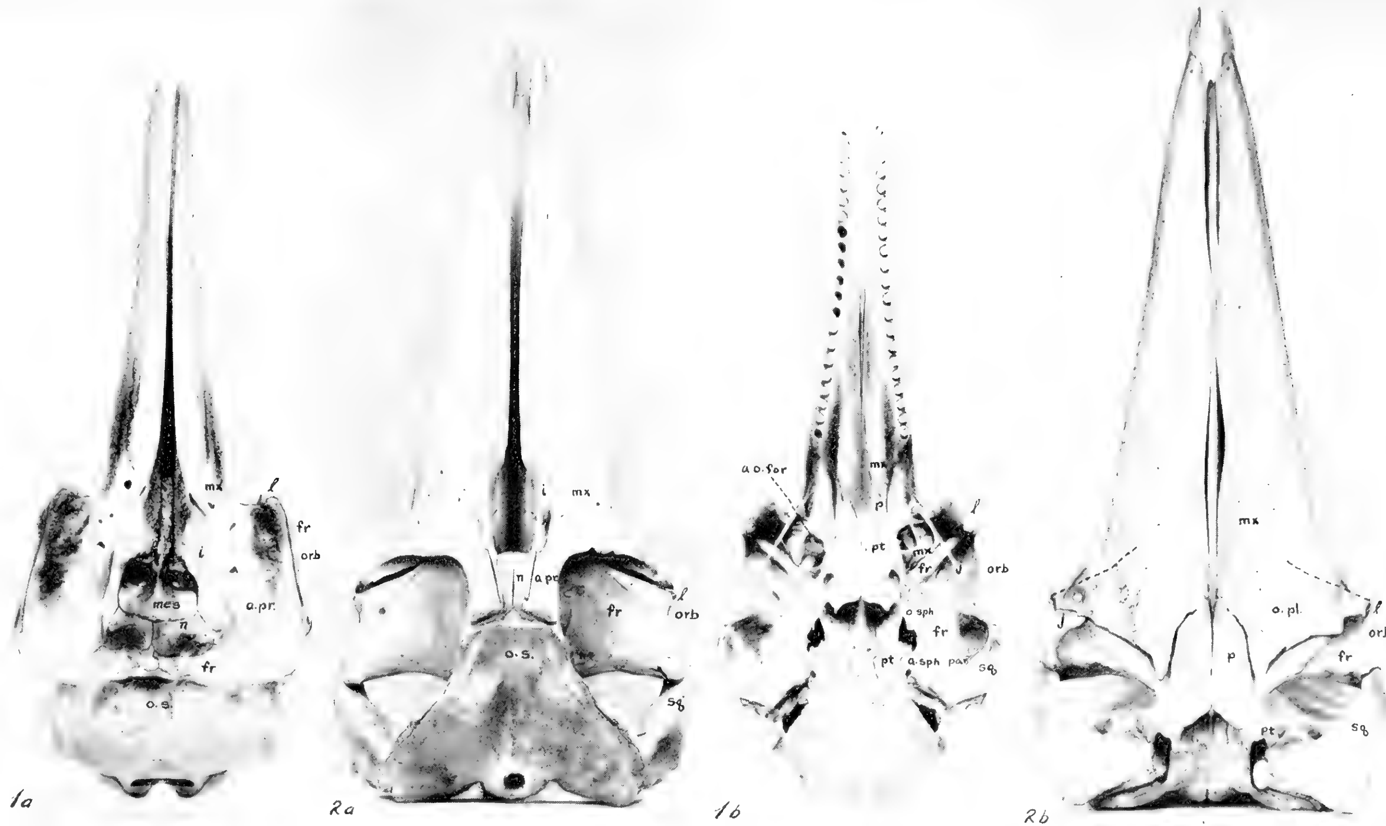
a. o. for. = Antorbital foramen.
a. pr. = Ascending process of maxillary.
a. sph. = Alisphenoid.
eth. = Ethmoid.
fr. = Frontal.
i. = Intermaxillary.
i. p. = Interparietal.
j. = Jugal.
l. = Lacrimal.
mes. = Mesethmoid.
mx. = Maxillary.
n. = Nasal.
occ. = Occipital.
o. pl. = Orbital plate of maxillary.
orb. = Orbit.
o. s. = Occipital shield.
o. sph. = Orbitosphenoid.
p. = Palatine.
par. = Parietal.
pt. = Pterygoid.
sq. = Squamosal.
v. = Vomer.
x. = Postero-internal angle of orbital plate of maxillary.
y. = Posterior termination of maxillary in median line.
+ = Position of anterior margin of occipital shield.
† = Position of narial orifice.

PLATE 1

Comparison between the skull of a toothed cetacean, fig. 1, and that of a baleen whale, fig. 2, to show the differences in method of telescoping described on page 4; dorsal and ventral aspects. (For comparison of lateral aspects see plate 6.)

FIG. 1. *Steno.* No. 49983, U. S. Nat. Mus. (The tympanic and periotic bones have been lost. The absence of the orbital plate of the maxillary is shown in fig. 1b by the exposed line of contact between the maxillary and the anterior border of the frontal.)

FIG. 2. *Balænoptera.* No. 236680, U. S. Nat. Mus. (The right tympanic bone and the left jugal have been lost. The great development of the orbital plate of the maxillary is shown in fig. 2b by the dotted line indicating the position of the anterior border of the frontal hidden in this view by the orbital plate.)

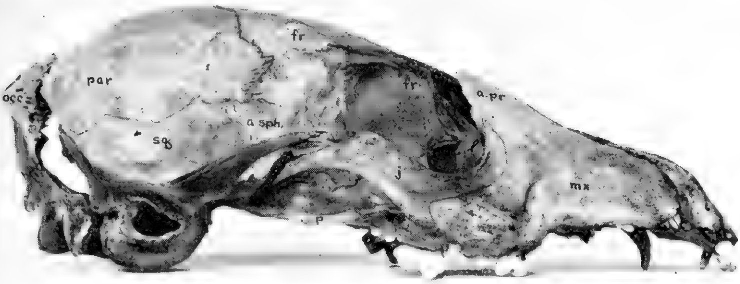


1. Toothed cetacean. 2. Baleen whale.

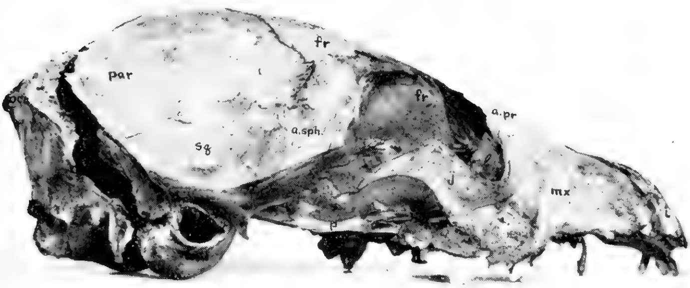
PLATE 2

Comparison between the skull of a young fox, fig. 1, and that of a young sea-lion, fig. 2; lateral aspect. Each skull has been photographed twice, from slightly different angles. The maxillary and occipital are disarticulated to show their differing mechanical relationships with the frontal and parietal respectively. In the fox the maxillary broadly overlies the frontal in the region of contact; the occipital and parietal are opposed. In the sea-lion the occipital broadly overlies the parietal in the region of contact; the maxillary and frontal are interlocked.

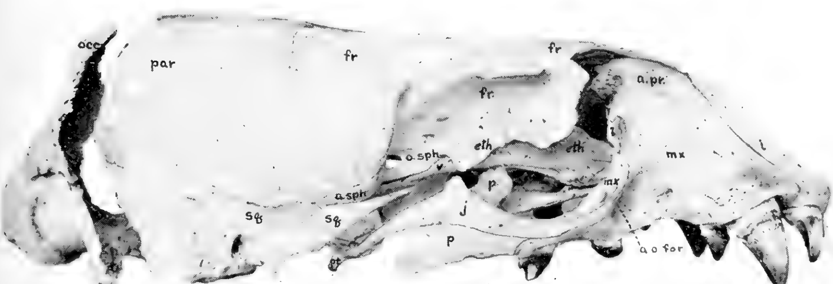
FIG. 1. *Vulpes.* No. 176017, U. S. Nat. Mus.
FIG. 2. *Eumetopias.* No. 151534, U. S. Nat. Mus.



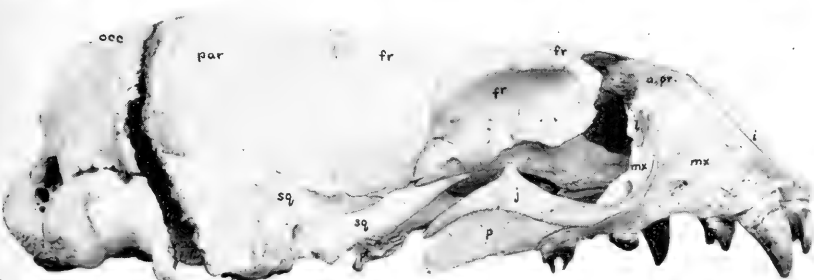
1a



1b



2a



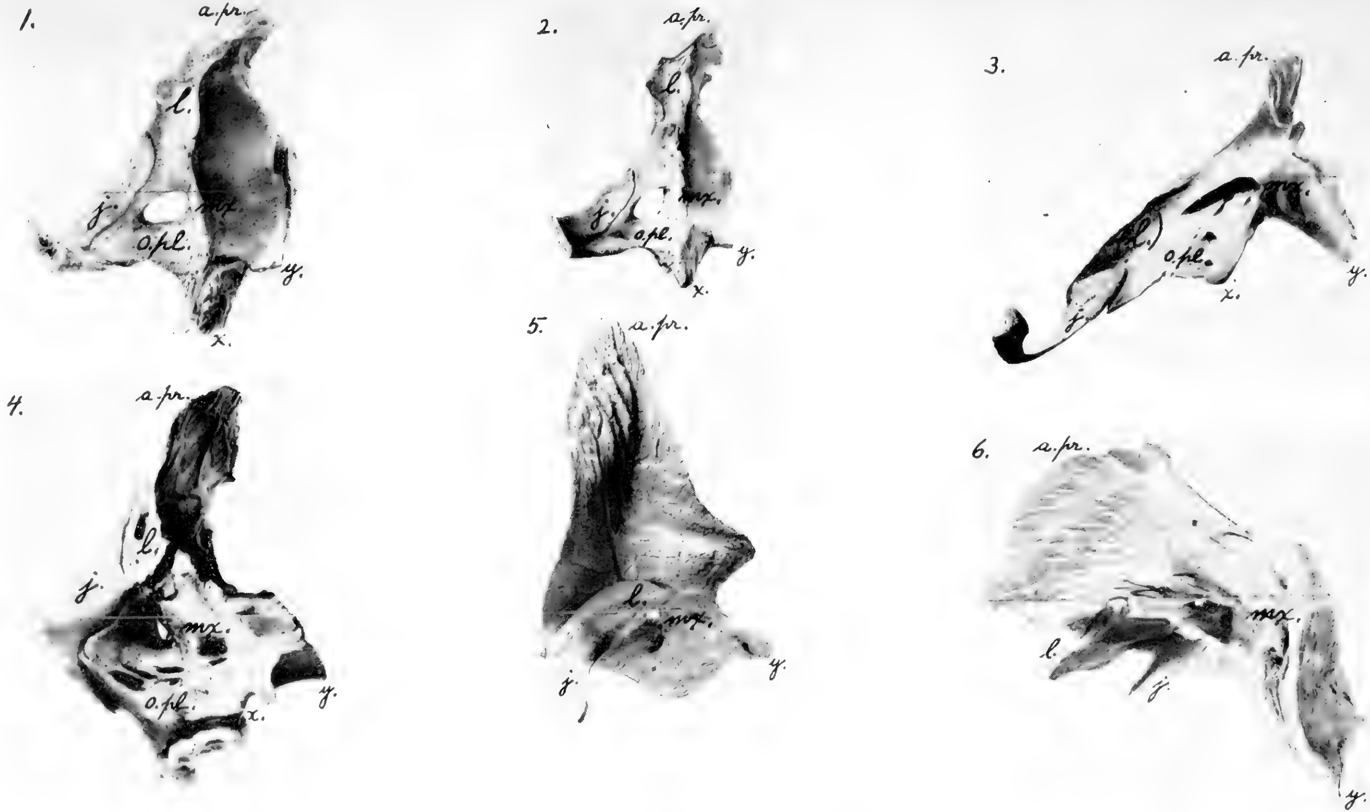
2b

1. Fox. 2. Sea-lion.

PLATE 3

Left maxillary bone removed from skull and viewed from behind to show features of similarity between a sea-lion, fig. 1, a furseal, fig. 2, and a baleen whale, fig. 3, and those between a fox, fig. 4 and two toothed cetaceans, figs. 5 and 6.

FIG. 1. *Eumetopias.* No. 239330, U. S. Nat. Mus.
FIG. 2. *Callorhinus.* No. 239329, U. S. Nat. Mus.
FIG. 3. *Balænoptera.* 20931, U. S. Nat. Mus. (The missing lacrimal lay in the depression of the maxillary in front of the jugal, as may be seen in fig. 3 of plate 6.)
FIG. 4. *Vulpes.* No. 239333, U. S. Nat. Mus.
FIG. 5. *Physeter,* very young. No. 49488, U. S. Nat. Mus.
FIG. 6. *Grampus.* No. 15773, U. S. Nat. Mus.



DETACHED MAXILLARY BONE VIEWED FROM BEHIND.

1. Sea-lion.
2. Furseal.
3. Baleen whale
4. Fox.
5. Sperm whale.
6. Grampus.

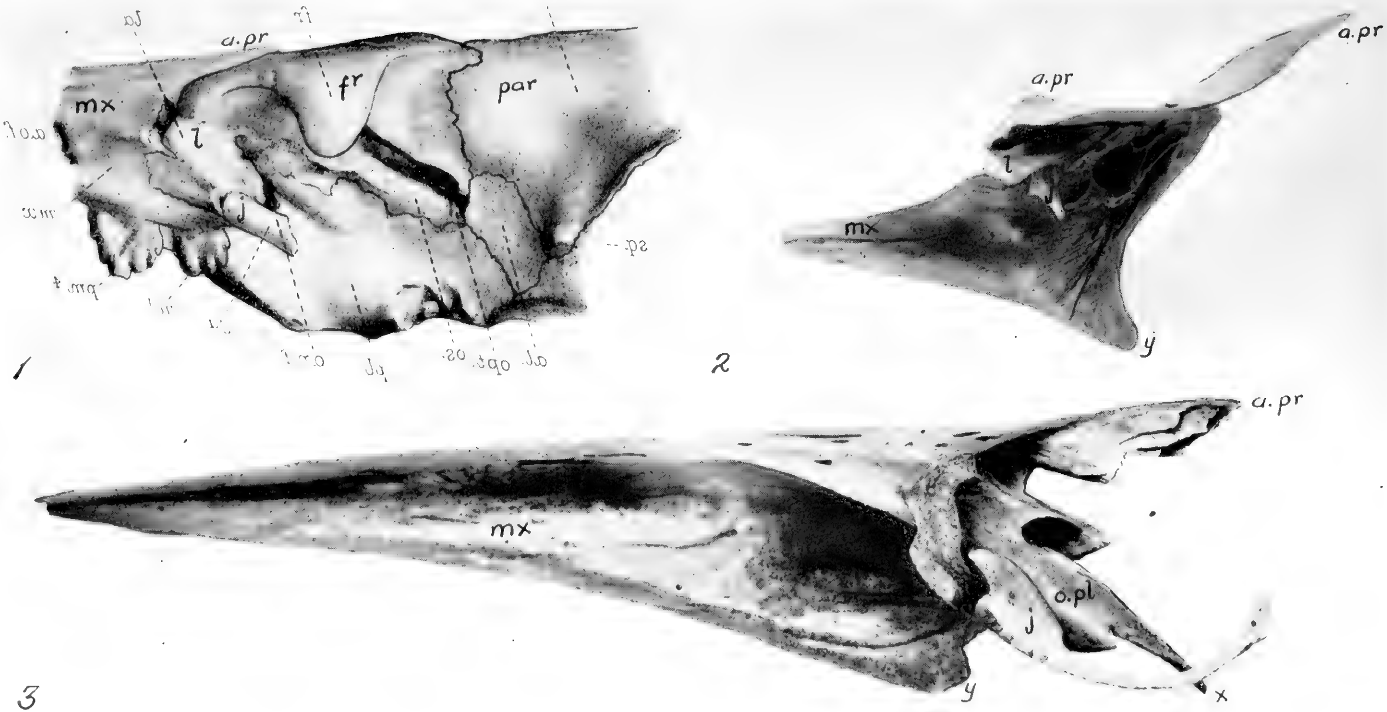
PLATE 4

Comparison between the lateral aspect of the maxillary of a zeuglodont, fig. 1, a toothed cetacean, fig. 2, and a baleen whale, fig. 3. The large orbital plate in the baleen whale is a structure which is absent in both the zeuglodont and the toothed cetacean.

FIG. 1. *Prozeuglodon* (from C. W. Andrews).

FIG. 2. *Grampus*. No. 15773, U. S. Nat. Mus.

FIG. 3. *Balænoptera*. No. 20931, U. S. Nat. Mus. (The missing lacrimal lay in the depression of the maxillary in front of the jugal, as may be seen in fig. 3 of plate 6.)



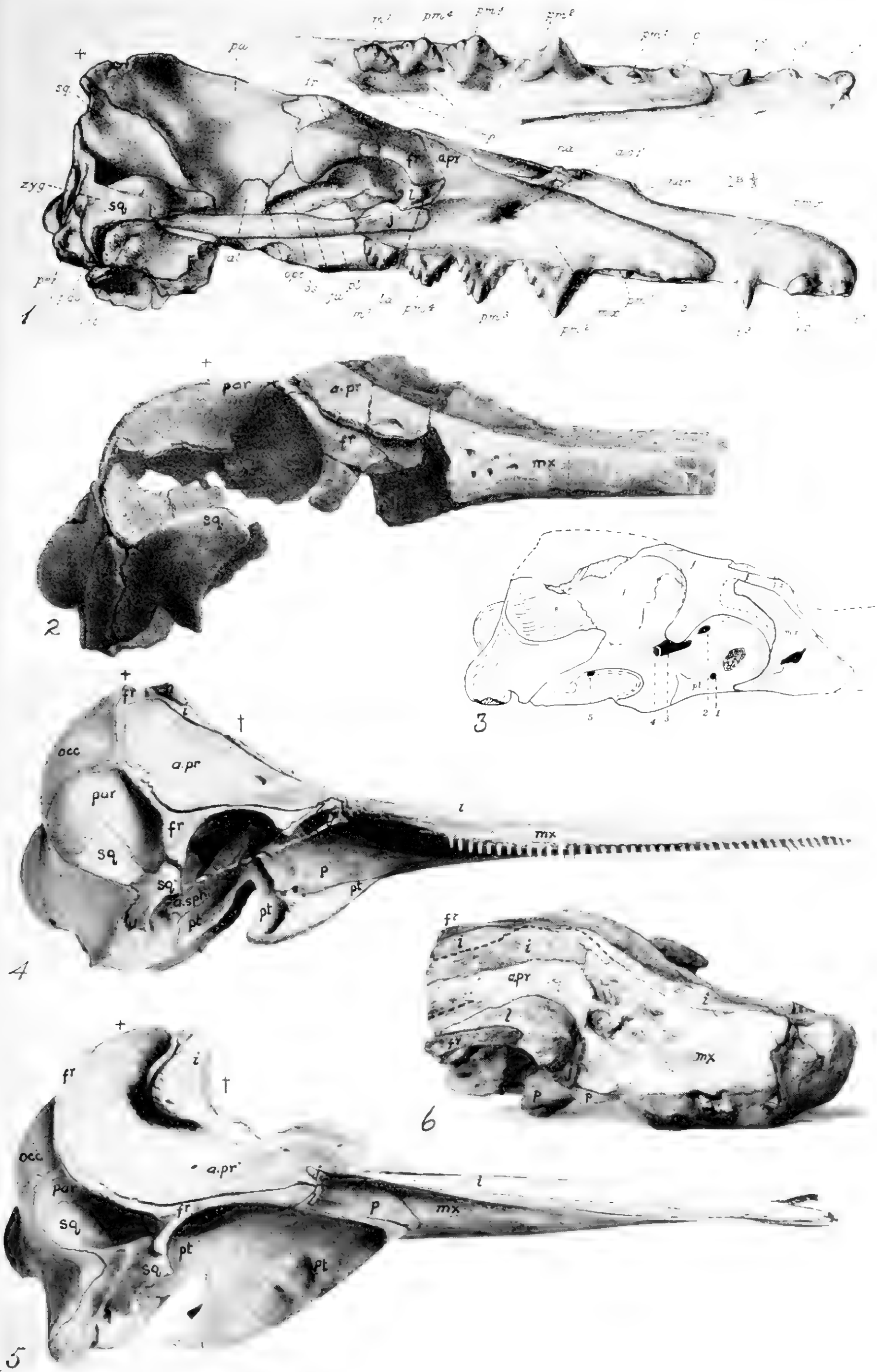
MAXILLARY VIEWED FROM THE SIDE.

1. Zeuglodont.
2. Toothed cetacean.
3. Baleen whale.

PLATE 5

Lateral aspect of skulls of zeuglodont, fig. 1 and toothed cetaceans, figs. 2-5.

FIG. 1. *Prozeuglodon* (from C. W. Andrews).
FIG. 2. *Agorophius* (from True).
FIG. 3. *Archæodelphis* (from G. M. Allen).
FIG. 4. *Delphinus.* No. 21525, U. S. Nat. Mus.
FIG. 5. *Mesoplodon.* No. 23346, U. S. Nat. Mus.
FIG. 6. *Xenorophus.* No. S. 402 W., Sloan Collection. (View of the type skull from slightly in front and above, to bring out particularly the terraced character of the maxillary, as shown by the level areas in the regions marked *mx* and *a. pr.* and the abruptly sloping area between them, and the wide overlapping of the maxillary and intermaxillary in the interorbital region; the upper dotted line indicates the original position of the maxillary border as shown on the opposite side of the specimen ; the lower dotted line indicates the approximate position of the lower border of the intermaxillary as seen in posterior view.) For other figures of *Xenorophus* see Kellogg, Smithsonian Misc. Coll., Vol. 76, No. 7, pls. 1-2, July 25, 1923.



1. Prozeuglodon.
2. Agorophius.
3. Archæodelphis.
4. Delphinus.
5. Mesoplodon
6. Xenorophus.

PLATE 6

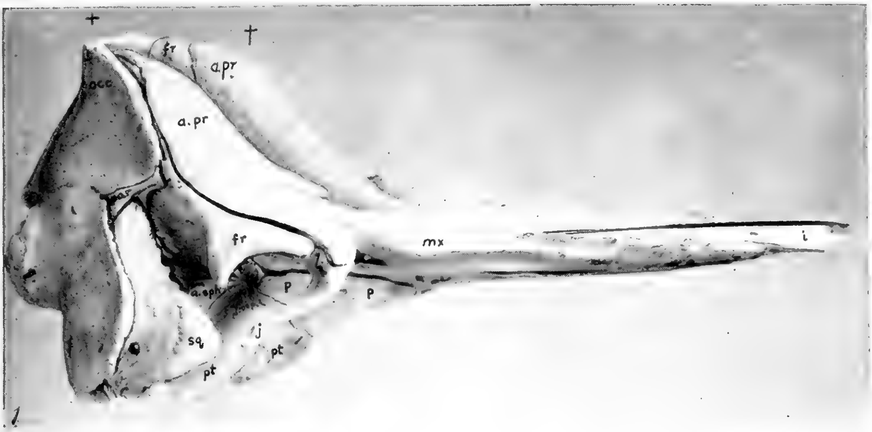
Lateral aspect of skulls of toothed cetaceans, figs. 1, 2, and baleen whales, figs. 3, 4.

FIG. 1. *Physeter,* very young. No. 49488, U. S. Nat. Mus.

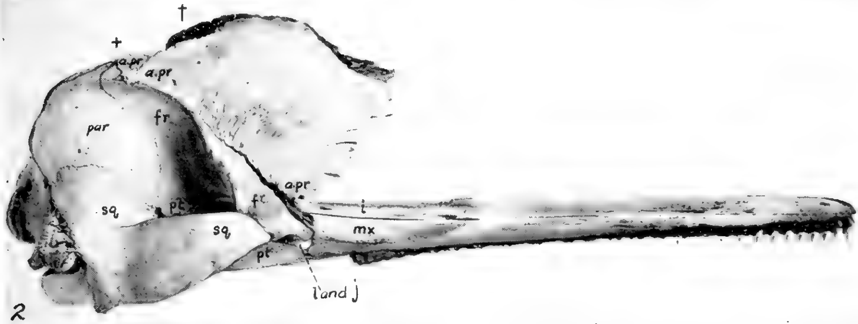
FIG. 2. *Platanista.* No. 172409, U. S. Nat. Mus. (The lacrimal and very short jugal are almost concealed beneath the overhanging edge of the orbit. The posterior orifice of the antorbital canal is visible above the edge of the zygomatic process of the squamosal in the region where the process comes in contact with the orbital portion of the frontal; above the orifice of the antorbital canal is a slit-like vacuity in the wall of the optic canal.)

FIG. 3. *Balænoptera.* No. 236680, U. S. Nat. Mus.

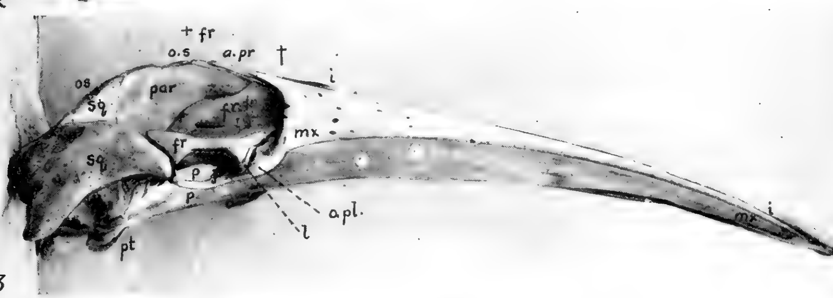
FIG. 4. *Eubalæna.* No. 23077, U. S. Nat. Mus.



1



2



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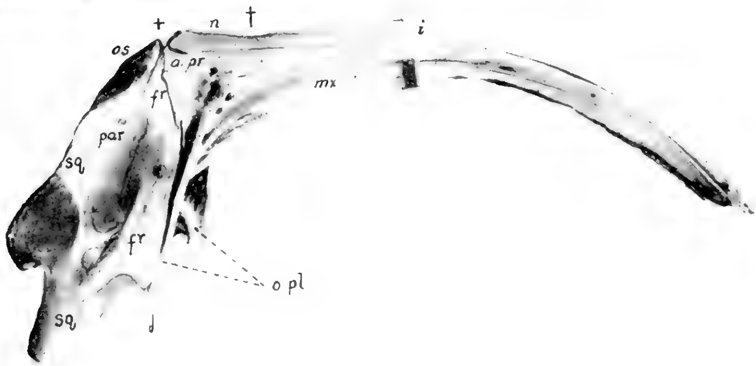


4

1. Physeter.
2. Platanista.
3. Balænoptera.
4. Eubalæna.

PLATE 7

Lateral aspect of skulls of highly modified toothed cetaceans, figs. 2, 3, 4, compared with that of a normal mammal, fig. 1.

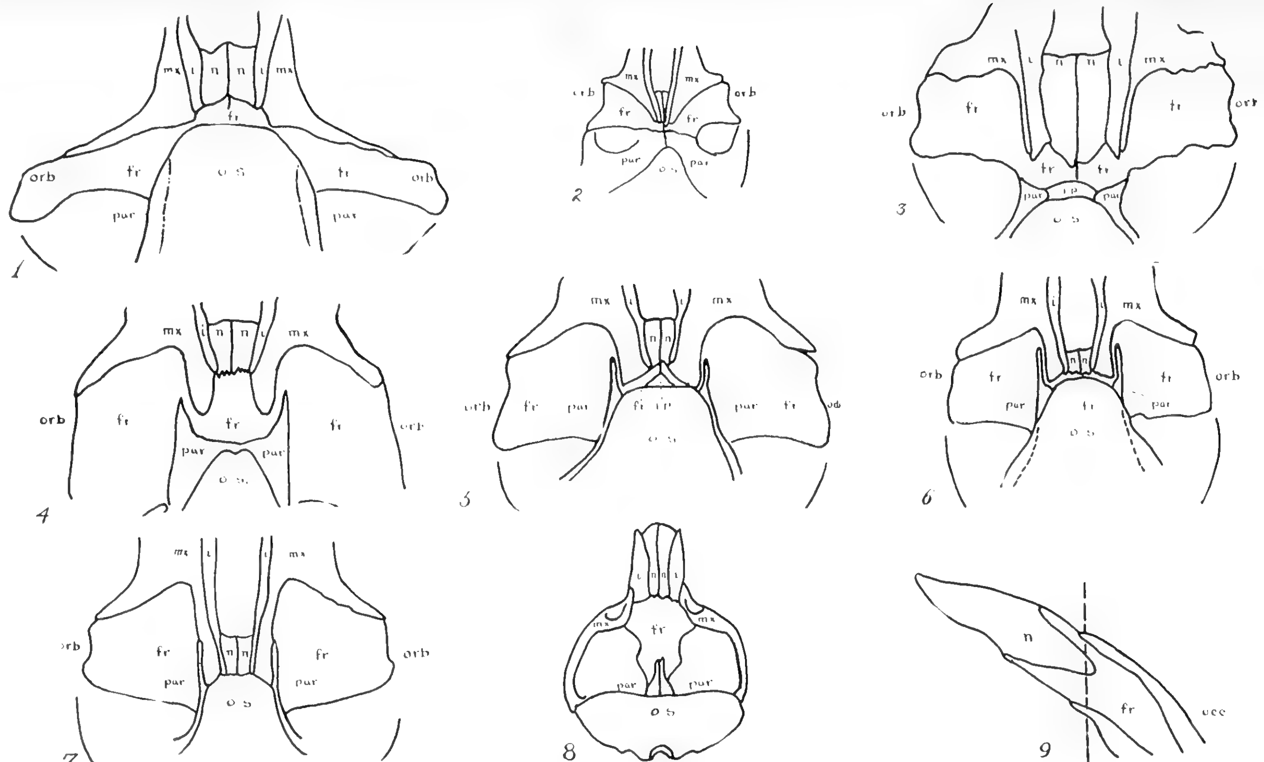
FIG. 1. *Cynogale.* No. 145587, U. S. Nat. Mus.
FIG. 2. *Stenodelphis.* No. 49494, U. S. Nat. Mus.
FIG. 3. *Kogia.* No. 22015, U. S. Nat. Mus.
FIG. 4. *Hyperoodon.* No. 14499, U. S. Nat. Mus.

1. Cynogale. 3. Kogia.
2. Stenodelphis. 4. Hyperoodon

PLATE 8

FIGS. 1-7 diagrams of telescoping in vertical region of mysticete skulls.

FIG. 1. *Eubalæna.* No. 23077, U. S. Nat. Mus.
FIG. 2. *Cetotherium* (from Van Beneden and Gervais).
FIG. 3. *Rhachianectes* (from R. C. Andrews).
FIG. 4. *Balænoptera,* young (from Eschricht).
FIG. 5. *Balænoptera* sp. No. 236680, U. S. Nat. Mus.
FIG. 6. *Balænoptera* sp. No. 16039, U. S. Nat. Mus.
FIG. 7. *Sibbaldus.* No. 49757, U. S. Nat. Mus.
FIG. 8. *Spalax* sp. (from Méhely). To show development of occipital shield and reduction of exposed area of parietals in a burrowing rodent.
FIG. 9. *Balæna* (from Eschricht). Longitudinal section of skull in frontal region to show presence of occipital, frontal and nasal at one vertical plane.



1. Eubalæna.
2. Cetotherium.
3. Rhachianectes.
4. Balænoptera.
5. Balænoptera.
6. Balænoptera.
7. Sibbaldus.
8. Spalax.
9. Balæna.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 76, NUMBER 6

DESCRIPTIONS OF NEW EAST INDIAN BIRDS OF THE FAMILIES TURDIDAE, SYLVIIDAE, PYCNONOTIDAE, AND MUSCICAPIDAE

BY
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(Publication 2721)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
JULY 16, 1923

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

DESCRIPTIONS OF NEW EAST INDIAN BIRDS OF THE FAMILIES TURDIDAE, SYLVIIDAE, PYCNONOTIDAE, AND MUSCICAPIDAE

By HARRY C. OBERHOLSER

Further study of the East Indian birds collected by Dr. W. L. Abbott on his various journeys has brought to light the following apparently undescribed forms.

The measurements given are all in millimeters; and the names of colors are from Ridgway's "Color Standards and Color Nomenclature."

TURDIDAE

COPSYCHUS SAULARIS PROSTHOPELLUS, subsp. nov.

Subspecific characters.—Similar to *Copsychus saularis docilis,* of Nepal, but averaging larger; has usually more black on the fourth rectrix (counting from the outermost); female much darker above and anteriorly below, with also buffy of sides and flanks darker.

Description.—Adult male, No. 86140, U. S. Nat. Mus.; Deep Bay, Hong Kong, China, November 12, 1881; P. L. Jouy and Dr. Dale. Upper parts, head, and neck all around, metallic bluish black; tail brownish black, edged with bluish black; posterior lower parts white, the sides tinged with gray and washed with pale buffy; the lower portion of the abdomen, the flanks, and crissum, washed with pale buffy.

Measurements of type.—Wing, 101.5 mm.; tail, 93; exposed culmen, 17.5[1]; tarsus 31.5; middle toe without claw, 18.5.

This is the race inhabiting southeastern China. How far to the south and southwest its range extends has not been determinable.

COPSYCHUS SAULARIS ERIMELAS, subsp. nov.

Subspecific characters.—Similar to *Copsychus saularis prosthopellus,* from southeastern China, but smaller, with decidedly more black on the fourth rectrix (from the outermost), and the under

[1] Approximate measurement; tip of maxilla somewhat damaged.

wing-coverts somewhat mixed with black; female with upper parts and throat paler and duller, and the buff of sides and flanks lighter.

Type.—Adult male, No. 95306, U. S. Nat. Mus.; Kankarit, Houndraw Branch, Tenasserim, June 27, 1879, C. T. Bingham.

Measurements of type.—Wing, 94 mm.; tail, 84; exposed culmen, 17; tarsus, 30; middle toe without claw, 17.5.

COPSYCHUS SAULARIS HALIBLECTUS, subsp. nov.

Subspecific characters.—Similar to *Copsychus saularis erimelas*, of northern Tenasserim, but somewhat larger, and with the fourth rectrix entirely black; female with upper parts darker, brighter, less grayish (more metallic bluish); and throat paler.

Type.—Adult female, No. 173179, U. S. Nat. Mus.; Domel Island, Mergui Archipelago, February 27, 1900; Dr. W. L. Abbott.

Measurements of type.—Wing, 93.5 mm.; tail, 83; exposed culmen, 17.8; tarsus, 28.5; middle toe without claw, 18.5.

This race appears to be confined to the Mergui Archipelago.

COPSYCHUS SAULARIS EPHALUS, nom. nov.

Subspecific characters.—Resembling *Copsychus saularis andamanensis*, from the Malay Peninsula, but larger, with a smaller bill; and with more black on the lining of the wing.

Type.—Adult male, No. 180979, U. S. Nat. Mus.; Tarussan Bay, Northwestern Sumatra, January 15, 1905; Dr. W. L. Abbott.

Measurements of type.—Wing, 105 mm.; tail, 91; exposed culmen, 20; tarsus, 31; middle toe without claw, 19.

This is the bird that is commonly called *Copsychus saularis musicus* (Raffles).[1] The basis of this name is merely a renaming of *Gracula saularis* Linnaeus, of India, as is evident from the opening sentences of Raffles' account of this bird:

"Lanius musicus.

"The Dial Bird, or *Turdus Mindanensis* of Gmelin and *Gracula saularis* of Linnaeus; now with more propriety placed under *Lanius*.

"It is one of the few singing-birds of India, and its note is pleasing."

The name *Turdus musicus* Raffles is thus a pure synonym of *Gracula saularis* Linnaeus, and the Sumatran race of the species requires a new name, which we have accordingly provided above.

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[1] *Lanius musicus* Raffles, Trans. Linn. Soc. Lond., XIII, pt. 2, 1822, after October, p. 307.

COPSYCHUS SAULARIS NESIARCHUS, subsp. nov.

Subspecific characters.—Similar to *Copsychus saularis ephalus,* from northwestern Sumatra, but somewhat smaller, and with white area on third and fourth rectrices (from outermost) much more extensive.

Type.—Adult male, No. 180075, U. S. Nat. Mus.; Lafau, Nias Island, western Sumatra, March 22, 1903; Dr. W. L. Abbott.

Measurements of type.—Wing, 103 mm.; tail, 91; exposed culmen, 20; tarsus, 31.5; middle toe without claw, 19.5.

This new race differs from *Copsychus saularis zacnecus* of the neighboring island of Simalur in having more white on the terminal portion of the fourth rectrix, and, in the male, no buff on the crissum.

COPSYCHUS SAULARIS NESIOTES, subsp. nov.

Subspecific characters.—Similar to *Copsychus saularis ephalus,* from Sumatra, but wing and tail shorter (not bill); third rectrix with less white and the fourth with none.

Type.—Adult male, No. 180537, U. S. Nat. Mus.; Tanjong Bedaan, Banka Island, southeastern Sumatra, June 4, 1904; Dr. W. L. Abbott.

Measurements of type.—Wing, 100 mm.; tail, 90; exposed culmen, 19.5; tarsus, 31.5; middle toe without claw, 18.5.

KITTACINCLA MELANURA PAGENSIS, subsp. nov.

Subspecific characters.—Similar to *Kittacincla melanura opisthochra,* from Pulo Lasia, Barussan Islands, western Sumatra, but smaller. Male with rufous posterior lower parts much paler. (No female examined.)

Description.—Type, male, No. 180079, U. S. Nat. Mus.; North Pagi Island, western Sumatra, January 9, 1903; Dr. W. L. Abbott. Upper parts metallic bluish black, except the rump, which is white; tail brownish black; wings dull black, some of the unmolted feathers dull brown, secondary wing-coverts edged with the color of the back; sides of head and of neck, together with the chin, throat, and jugulum, like the back; posterior lower parts between cinnamon rufous and tawny, paler on the middle of the abdomen; lining of wing ochraceous buff, edges of wing blackish.

Measurements of type.—Wing, 83 mm.; tail, 103; exposed culmen, 15; height of bill at base, 5.5; tarsus, 25.5; middle toe without claw, 15.5.

This race is distinguishable from *Kittacincla melanura hypoliza,* of Simalur Island, and *Kittacincla melanura melanura,* of Nias Island, by its smaller size and much paler rufous of the posterior lower parts. It is apparently confined to the Pagi Islands.

The present species has an interesting geographical distribution, since all the subspecies occur, so far as now known, only on islands of the Barussan chain, off the western coast of Sumatra, and on islands in the Java Sea. These races are as follows:

1. *Kittacincla melanura melanura* Salvadori. Nias Island, Barussan Islands.
2. *Kittacincla melanura hypoliza* Oberholser. Simalur Island, Barussan Islands.
3. *Kittacincla melanura opisthochra* Oberholser. Lasia and Babi Islands, Barussan Islands.
4. *Kittacincla melanura pagensis* Oberholser. Pagi Islands, Barussan Islands.
5. *Kittacincla melanura nigricauda* Vorderman. Kangean Islands and Pulo Mata Siri, in the Java Sea.

KITTACINCLA MALABARICA PELLOGYNA, subsp. nov.

Subspecific characters.—Similar to *Kittacincla malabarica malabarica* of India, but female darker. Resembling *Kittacincla malabarica interposita,*[1] but larger, especially the wing and bill; and with more white on the tail.

Description.—Type, adult female, No. 173176, U. S. Nat. Mus.; Bok Pyim, Tenasserim, February 14, 1900; Dr. W. L. Abbott. Upper parts blackish plumbeous, except the rump and upper tail-coverts, which are white; tail black, slightly brownish, the tips of the feathers white; wings rather dark fuscous black, the edges of the primaries and secondaries, with the greater and middle coverts, olive brown, the lesser coverts between slate gray and dark plumbeous; chin between fuscous and hair brown; sides of the head and of neck, together with throat and jugulum, fuscous black, overlaid somewhat with blackish plumbeous; breast, sides, and flanks, between cinnamon rufous and tawny, shading to nearly pure white on the middle of the abdomen; crissum between cinnamon buff and clay color; thighs dull white; outer under wing-coverts blackish, margined with neutral gray and whitish; the remaining portion of lining of wing tinged on the axillars and on the innermost coverts with buff.

Measurements of type.—Wing, 86 mm.; tail, 107.5; exposed culmen, 13.5; height of bill at base, 5; tarsus, 24.5; middle toe without claw, 16.

[1] *Kittacincla malabarica interposita* Robinson and Klöss, Journ. Fed. Malay States Mus., X, No. 4, December, 1922, p. 262 (Daban, South Annam).

This form of the species occupies at least the northern and middle portions of the Malay Peninsula. Examples from Johore are intermediate between *Kittacincla malabarica pellogyna* and the Sumatra race described below, but are referable to the former. As in many of the subspecies of *Kittacincla malabarica,* the racial characters are more evident in the female than in the male.

KITTACINCLA MALABARICA LAMPROGYNA, subsp. nov.

Subspecific characters.—Similar to *Kittacincla malabarica pellogyna,* from the Malay Peninsula, but female with upper parts lighter, more grayish; the throat, jugulum, breast, and sides of body, lighter.

Type.—Adult female, No. 173173, U. S. Nat. Mus.; St. Luke Island, Mergui Archipelago, January 21, 1900; Dr. W. L. Abbott.

Measurements of type.—Wing, 87 mm.; tail, 117.5; exposed culmen, 13; height of bill at base, 5; tarsus, 25; middle toe without claw, 16.

Although apparently confined to the Mergui Archipelago, this race is in color somewhat intermediate between *Kittacincla malabarica malabarica,* of India, and *Kittacincla malabarica pellogyna,* of the Malay Peninsula. From the former it differs in the darker colors of the female.

KITTACINCLA MALABARICA MALLOPERCNA, subsp. nov.

Subspecific characters.—Allied to *Kittacincla malabarica pellogyna,* of the Malay Peninsula, but female with upper parts darker, and with more metallic sheen; breast and sides more deeply rufescent. Male very much like the same sex of *Kittacincla malabarica pellogyna,* except that the rufous of lower parts is somewhat darker.

Type.—Adult female, No. 178969, U. S. Nat. Mus.; Sing Kep Island, Berhala Strait, off southeastern Sumatra, May 18, 1901; Dr. W. L. Abbott.

Measurements of type.—Wing, 85 mm.; tail, 99; exposed culmen, 15; height of bill at base, 6; tarsus, 24; middle toe without claw, 16.5.

This is apparently the form of *Kittacincla malabarica* that inhabits the mainland of Sumatra as well as the islands along its eastern side, with the exception of Banka and Billeton.

KITTACINCLA MALABARICA ABBOTTI,[1] subsp. nov.

Subspecific characters.—Similar to *Kittacincla malabarica mallopercna,* but posterior lower parts much darker and more uniformly rufous.

[1] Named for Dr. W. L. Abbott.

Type.—Adult female, No. 180538, U. S. Nat. Mus.; Tanjong Bedaan, Banka Island, southeastern Sumatra, June 7, 1904, Dr. W. L. Abbott.

Measurements of type.—Wing, 86 mm.; tail, 104; exposed culmen, 15; height of bill at base, 6; tarsus, 24; middle toe without claw, 15.5.

KITTACINCLA MALABARICA ZAPHOTINA, subsp. nov.

Subspecific characters.—Similar to *Kittacincla malabarica abbotti,* from the island of Banka, but female with throat and upper parts, including wings and tail, much darker more blackish (less slaty); rufous of posterior lower surface somewhat darker and duller.

Type.—Adult female, No. 178140, U. S. Nat. Mus.; central Borneo, 1899; Dr. A. W. Nieuwenhuis.

Measurements of type.—Wing, 95.5 mm.; tail, 109; exposed culmen, 16; height of bill at base, 6.5; tarsus, 26.5; middle toe without claw, 17.

This race occupies the central and southwestern portion of Borneo. From *Kittacincla malabarica suavis,* of southeastern Borneo, its female differs in having the upper parts and throat lighter, with less metallic sheen, and the rufous of lower surface somewhat lighter.

SYLVIIDAE

ORTHOTOMUS ATROGULARIS EUMELAS, subsp. nov.

Subspecific characters.—Similar to *Orthotomus atrogularis atrogularis,* from the Malay Peninsula, but with upper parts darker and throat more solidly black.

Description.—Type, adult male, No. 180597, U. S. Nat. Mus.; Tanjong Bedaan, Banka Island, southeastern Sumatra, June 3, 1904; Dr. W. L. Abbott. Pileum dark cinnamon rufous, the remaining upper parts warbler green; tail buffy olive, the feathers edged with pyrite yellow, their tips sulphine yellow; wings fuscous, edged with warbler green; upper half of the sides of the head, together with the lores, dark cinnamon rufous; auriculars, chin, and upper throat, dull white, a little mixed with blackish; sides of neck warbler green; the rest of the throat, together with the jugulum, black; upper breast neutral gray, streaked and mixed with white; crissum, citrine yellow; remainder of lower parts white, but the sides and flanks washed with greenish yellow; thighs between ochraceous tawny and buckthorn brown; edges of wing and lining of wing, anteriorly amber yellow, posteriorly white, a little washed with amber yellow.

Measurements of type.—Wing, 43 mm.; tail, 43; exposed culmen, 13; height of bill at base, 3; tarsus, 20; middle toe without claw, 9.5.

No specimens of this species from the island of Sumatra have been examined, but this is probably the subspecies occurring there.

PYCNONOTIDAE

AEGITHINA TIPHIA MICROMELAENA, subsp. nov.

Subspecific characters.—Similar to *Aegithina tiphia tiphia,* from Bengal, India, but with black of upper surface confined to pileum and cervix; remainder of upper parts darker; and size somewhat smaller.

Description.—Type, adult male, No. 180548, U. S. Nat. Mus.; Tanjong Tedong, Banka Island, June 5, 1904; Dr. W. L. Abbott. Pileum, cervix, and scapulars (excepting the white inner tuft), glossy, slightly bluish black; back olive green; upper tail-coverts bluish black; tail black with a slightly bluish sheen; primaries and secondaries, fuscous black, their inner margins basally white, the outer webs black on their basal portion, the median area somewhat narrowly edged with yellowish white; rest of the wing black with a slight bluish sheen, but the middle and greater coverts broadly tipped with white, and the tertials edged externally with yellowish white and warbler green, internally with white; lores, a narrow superciliary stripe to the middle of the eye, all the anterior lower parts to the breast, inclusive, together with the sides of the head and of neck up to the middle of the eye, rich gamboge yellow; rest of lower parts lemon yellow, but the flank tufts white, the sides tinged and mixed with olive green; posterior lower part of thighs washed with yellow; rest of thighs dull yellow; lining of wing white, but the inner edge light lemon yellow.

Measurements of type.—Wing, 61.5 mm.; tail, 47.5; exposed culmen, 16.5; tarsus, 19; middle toe without claw, 11.

So far as now determinable, this new race is confined to the island of Banka, off the eastern end of Sumatra.

AEGITHINA TIPHIA DAMICRA, subsp. nov.

Subspecific characters.—Resembling *Aegithina tiphia micromelaena,* from the island of Banka, but smaller; pileum and cervix, olive green like the back, instead of black; and yellow lower parts duller, more tinged with greenish.

Type.—Adult male, No. 178144, U. S. Nat. Mus.; Smitau, Kapuas River, southwestern Borneo, December 14, 1893; J. Büttikofer.

Measurements of type.—Wing, 57 mm.; tail, 41.5; exposed culmen, 13.8; tarsus, 17.5; middle toe without claw, 10.

This bird is, in some respects, most closely allied to *Aegithina tiphia viridis* of Northern Borneo, but it differs from that race in its smaller size, lighter upper parts, greenish forehead, and duller, more greenish lower surface.

AEGITHINA TIPHIA ZOPHONOTA, subsp. nov.

Subspecific characters.—Similar to *Aegithina tiphia damicra,* of southwestern Borneo, but upper parts decidedly paler.

Type.—Adult male, No. 183008, U. S. Nat. Mus.; Taham, central eastern Borneo, April 13, 1914; H. C. Raven.

Measurements of type.—Wing, 58 mm.; tail, 42.5; exposed culmen, 13.8; tarsus, 17; middle toe without claw, 10.

From *Aegithina tiphia viridis,* of northern Borneo, this form may be readily distinguished by its smaller size, olive green forehead, and duller, more greenish lower parts.

With the above proposed additions, the recognizable subspecies of *Aegithina tiphia* are as follows:

1. *Aegithina tiphia tiphia* (Linnaeus). Northern India, Burma, the Malay Peninsula, and Sumatra.
2. *Aegithina tiphia multicolor* (Gmelin).[1] Ceylon, southern and central India.
3. *Aegithina tiphia horizoptera* Oberholser. Nias Island in the Barussan Islands, off western Sumatra.
4. *Aegithina tiphia micromelana* Oberholser. Banka Island, off eastern Sumatra.
5. *Aegithina tiphia damicra* Oberholser. Southwestern Borneo.
6. *Aegithina tiphia zophonota* Oberholser. Eastern Borneo.
7. *Aegithina tiphia viridis* (Bonaparte). Northwestern Borneo.
8. *Aegithina tiphia aequanimis* Bangs. Palawan Island and Dumaran Island, in the Philippine Islands.
9. *Aegithina tiphia scapularis* (Horsfield). Java.

MUSCICAPIDAE

CULICICAPA CEYLONENSIS CALOCHRYSEA, subsp. nov.

Subspecific characters.—Similar to *Culicicapa ceylonensis ceylonensis,* from India, but with upper parts paler more golden (less greenish), especially the edgings of the tail; throat paler; posterior lower surface brighter; and the crissum somewhat more golden.

[1] *Fringilla multicolor* Gmelin, Syst. Nat. I, ii, 1789 (before April 20), p. 924 ("insula Zeylon"). This name has 40 pages anteriority over *Motacilla zeylonica* Gmelin; is of identical application; and therefore seems to be the proper name for this race.

Description.—Type, adult male, No. 95332, U. S. Nat. Mus.; Quaymos, Choung, Thoungyin River, Tenasserim, February 2, 1880; C. T. Bingham, original number, 295. Pileum deep mouse gray; upper parts, including the edges of the wing-coverts, yellowish warbler green, the rump and upper tail-coverts being most yellowish; tail between hair brown and fuscous, the feathers edged with yellowish, between aniline yellow and sulphine yellow; wings fuscous, the edges of the primaries, secondaries, and tertials between sulphine yellow and lemon chrome; side of the head and of neck like the cervix; chin and throat, light mouse gray, but the middle of throat and of jugulum pale mouse gray; posterior lower parts rich lemon chrome, a little dull, the sides of the body washed with olivaceous; lining of wings between penard yellow and picric yellow.

Measurements of type.—Wing, 61.5 mm.; tail, 55.5; exposed culmen, 7; tarsus, 13; middle toe without claw, 7.5.

This subspecies ranges from middle Tenasserim north apparently to Nepal. How far east or west it extends we are not, with our present material, able to determine.

CULICICAPA CEYLONENSIS ANTIOXANTHA, subsp. nov.

Subspecific characters.—Similar to *Culicicapa ceylonensis calochrysea,* from northern Tenasserim, but darker above, including the pileum; back usually less yellowish; and throat darker.

Type.—Adult male, No. 169979, U. S. Nat. Mus.; Khaw Sai Dow, Trang, Lower (Peninsular) Siam, February 8, 1899; Dr. W. L. Abbott.

Measurements of type.—Wing, 60 mm.; tail, 48.5; exposed culmen, 8.5; tarsus, 10.3; middle toe without claw, 7.

This race occupies probably all the southern portion of the Malay Peninsula. Birds from southern Tenasserim seem also referable here, though verging toward *Culicicapa ceylonensis calochrysea.*

CULICICAPA CEYLONENSIS PELLOPIRA, subsp. nov.

Subspecific characters.—Resembling *Culicicapa ceylonensis antioxantha,* from the Malay Peninsula, but with the yellowish edgings of tail darker, more olivaceous; posterior lower parts more richly golden yellow; sides and flanks more strongly tinged with olive.

Type.—Adult male, No. 220127, U. S. Nat. Mus.; Tjibodas, Mt. Gedé, 4,500 feet altitude, Java, September 3, 1909; William Palmer.

Measurements of type.—Wing, 61 mm.; tail, 51.5; exposed culmen, 8.5; tarsus, 12.3; middle toe without claw, 7.8.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 76, NUMBER 7

DESCRIPTION OF AN APPARENTLY NEW TOOTHED CETACEAN FROM SOUTH CAROLINA

(WITH TWO PLATES)

BY
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(PUBLICATION 2723)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
July 25, 1923

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

DESCRIPTION OF AN APPARENTLY NEW TOOTHED CETACEAN FROM SOUTH CAROLINA

By REMINGTON KELLOGG

BUREAU OF BIOLOGICAL SURVEY, U. S. DEPARTMENT OF AGRICULTURE

(WITH TWO PLATES)

Mr. Earle Sloan of Charleston, South Carolina, has given me permission to study the skull of a fossil dolphin from that state. An account of a geological section [1] near where this specimen was obtained was published in 1908. The fossil may be described as follows:

XENOROPHUS, new genus

Type.—*Xenorophus sloanii,* new species.

Diagnosis.—Resembling *Agorophius* and *Archaeodelphis* in the presence of an intertemporal constriction. Differing from these genera (so far as their characters are known) in the following peculiarities: premaxilla widened posteriorly so that it extends conspicuously outward under the maxillary in the interorbital region; lachrymal very large, sheathing most of the upper margin of the orbit; maxillary abruptly sloping in region immediately in front of orbits, its anterior and posterior portions horizontal; palatine extending forward as far as the anterior margin of the alveolus for the last molar. Teeth with finely serrated cutting edges and rugose enamel. Seven are double-rooted. In front of these the remaining portion of the rostrum bears the alveoli of two single-rooted teeth.

XENOROPHUS SLOANII, new species

Type.—Cat. No. S. 402 W., Sloan Collection (now on deposit in Section of Vertebrate Paleontology, United States National Museum). Incomplete skull, including the interorbital region and the major portion of the rostrum. Six molars are in place and an additional one was found imbedded in the matrix above palate.

[1] Sloan, E., Catalogue of the mineral localities of South Carolina. Bull. No. 2, ser. 4, South Carolina Geol. Surv., Columbia, p. 286, No. 402, 1908.

Type locality.—Marl at Woodstock Station on the Ingleside Mining Company property, Berkeley County, South Carolina. Near 80° 5′ Lat., and 32° 58′ Long.; shown on Ravenels Quadrangle, United States Geological Survey. The following statement has been furnished by Mr. Sloan:

At a depth of fifteen feet below the upper surface of the marl the specimen was exhumed and given by the Superintendent to the writer, who examined the pit on numerous occasions, and who considers the upper part of the Ashley-Cooper marl as probably Oligocene, and the lower part, which is separated by a layer of rounded pebbles in some localities, and by a layer of oyster shells in others, as Upper Jackson. The upper marl is of homogeneous texture, and drab green color; and contains 74 per cent calcium carbonate; it encloses occasional fossil shells of which the following have been identified: *Cassis* (*Morio*) *petersoni* Con., *Ostrea trigonalis* Con., *Volutilithes petrosa* Con., and *Pecten calvatus* Morton.

Dorsal view.—The tapering rostrum (pl. 1) exhibits many modifications present in *Squalodon calvertensis*.[1] Although constricted at the level of the maxillary notches, the rostrum swells out in front of the last molar, and then as far as preserved, gradually tapers toward the extremity. The mesorostral gutter apparently was open the full length of the rostrum, though the premaxillae may have approximated each other very closely near the level of the first two-rooted teeth. Distally, this gutter is formed by the premaxillae, which meet mesially and ventrally in a linear suture in front of the alveoli for the first two-rooted teeth; proximally the vomer and the premaxillae contribute to its formation. This gutter is partially roofed by the arched premaxillae. The distal extremity of the vomer appears at the level of the anterior margins of the alveoli for the first two-rooted teeth. It takes part in the formation of the lateral walls of the mesorostral gutter, sheathing the premaxillary bones, but the contact between the vomer and the premaxilla has its posterior limit at the level of the maxillary foramina. Slender remnants of the thin ascending plates of the vomer are present on each side of the frontal fontanelle, but they have been damaged in the region of the nasal passages. Ventrally, the external wall of the nasal passage was no doubt formed by the pterygoid bone, but since both pterygoids are missing, no further comments are necessary. Inferiorly the palatine bounds the nasal passage, and superiorly the premaxilla contributes a portion of the wall. No ascending process of the palatine appears to have been

[1] Kellogg, R., Description of two squalodonts recently discovered in the Calvert Cliffs, Maryland; and notes on the shark-toothed cetaceans. Proc. U. S. Nat. Mus., vol. 62, art. 16, Publ. 2462, pl. 1, 1923.

present. At the end of the vomerine gutter and some distance above it, there is a single large frontal fontanelle through which the nasal branches of the ophthalmic (V) nerve probably passed.

The premaxilla is narrowest near the third two-rooted tooth. Posterior to this tooth, the premaxilla commences to expand horizontally and attains its greatest width on the rostrum above the sixth two-rooted tooth. At the level of the maxillary foramen the exposed portion of the premaxilla is relatively narrow and from this point posteriorly it is hidden for the most part by the overlying frontal plate of the maxilla. Along the external boundary of the nasal aperture the premaxilla has been elevated to form a thin edged crest which commences in front of the maxillary foramen and follows the internal border of the maxilla backward beyond the posterior margin of the nasal. The anterior border of the nasal aperture is formed by the upturned inner margins of the premaxillae. At its posterior extremity, the left premaxilla has a maximum breadth of 50 mm., although it is largely hidden by the overlying maxilla.

Though the braincase is absent, it is fairly certain that this skull was characterized by a very narrow interorbital constriction. The maxillae and premaxillae terminate above the anterior margins of the temporal fossae. The premaxilla overspreads the frontal and a portion of its supraorbital process, and in turn is overlapped by the frontal plate of the maxilla though a wide triangular area is exposed behind and above the postero-internal margin of the maxilla. The maxilla increases in width from the extremity of the rostrum posteriorly and attains its greatest width at the level of the nasals, but because of the peculiar position of the lachrymal does not reach the outer edge of the orbit. The internal margin of the maxilla is in contact with the premaxilla for its entire length.

The rostrum is depressed below the level of the orbits and in correlation with this modification each maxilla is strongly excavated or hollowed out between the maxillary notch and the fifth two-rooted tooth. The broad base of the rostrum is formed mainly by the lateral expansion of the maxillae. On the left side of the rostrum, the roots of the fifth and sixth two-rooted teeth have pierced the dorsal face of the maxilla and have been clinched.

In contrast to all other known cetaceans, the lachrymal projects backward along the outer margin of the supraorbital process of the frontal as far as the postero-external angle of the maxilla and the posterior margin of the eye. It agrees with certain forms, such as *Kogia,* in that it curves downward in front of the supraorbital process and on the ventral face of the skull extends inward beyond the infraorbital foramen. From a dorsal view it is triangular in outline and is of approximately the same thickness as the frontal plate of the maxilla. There is no preorbital process or apophysis. The distal end of the jugal is present on both sides of this skull. This portion of the jugal is subtriangular in outline and occupies a median position in the maxillary notch. It is merely a small wedge which has forced its way in between the maxilla and the lachrymal from both of which it is separated by sutures.

The nasal bones are about equal in length to the maximum breadth between the premaxillae of the exposed portions of the frontals on the vertex of the skull. In position, the nasals are considerably posterior to those of *Archaeodelphis*[1] and probably are farther back than those of *Agorophius,* both nasals of which are missing. The anterior margins of the nasal bones in the *Xenorophus* skull do not extend beyond the middle of the supraorbital process. The nasals do not completely roof over the nasal passages, and hence the anterior nares open in almost the same direction as in *Squalodon calvertensis.* On each side the nasals are bounded by the broad premaxilla.

The frontals are much reduced in extent on the vertex, being overspread by the premaxillae laterally and by the nasals anteriorly. The supraorbital process slopes forward; its postero-external extremity appears to be imperfect and probably curved downward. A close examination of the posterior ends of the frontals does not reveal any evidence for sutural union with the parietals at this level and the surfaces correspond to similar fractures elsewhere on this skull. The curvature of the sides of the skull in the temporal fossae, and the narrowness of the frontals on the vertex is evidence that this skull was characterized by a better marked intertemporal constriction than in either *Archaeodelphis* or *Agorophius.* In both of these forms, each parietal sends forward a median process which fits into a corresponding depression in the combined frontals.

Lateral view.—The dorsal outline of the rostrum is almost straight in front of the maxillary notches, but slopes downward toward the extremity. As a whole the skull appears to have been rather slender, and the height at the vertex is proportionately low in comparison with that of the base of the rostrum. The crest-like ridge of the premaxilla is the highest point of the dorsal profile anterior to the intertemporal constriction. The alveolus for the last two-rooted tooth terminates

[1] Allen, G. M., A new fossil cetacean. Bull. Mus. Comp. Zool. at Harvard College, vol. 45, No. 1, pl. 1, fig. 1, 1921.

23.2 mm. in advance of the maxillary notch. The greatest vertical depth of the supraorbital process of the left frontal is 12.5 mm., and the greatest length is 61 mm.

All of the braincase posterior to the presphenoid is missing. The side of the presphenoid is visible from this view. Of the parietals practically nothing remains except in the temporal fossa. Here a portion of the lateral wing which overspreads the frontal and extends forward to the posterior rim of the supraorbital process can be traced. Below the supraorbital process and between the vomer and the arched palatine is the exposed nasal passage.

Ventral view.—The most striking feature of the ventral aspect (pl. 2) is the relatively large size of the palatine bones. Anteriorly they extend forward beyond the maxillary notches, but in *Archaeodelphis* they terminate slightly posterior to them. The palatine region of the *Agorophius* skull was not figured. In contrast to *Archaeodelphis,* the alveolus of the last molar in *Xenorophus* is not situated in advance of the anterior margin of the palatine. Externally the palatine contributes the lower and outer margins for the infraorbital foramen. Each palatine attains its maximum horizontal expansion in a line with the inferior margin of the jugal. The emargination of the anterior end of each palatine is quite noticeable and rather irregular. Together they are almost as broad as the space between the tooth rows, but they were not in contact mesially.

The vomer first appears as a splint-like bone inserted between the maxillae, commencing near the anterior margin of the alveoli for the first two-rooted teeth, and disappearing at the level of the last tooth. It appears again between the palatines at the level of the infraorbital foramina and extends backward beyond their posterior margins. The vomer is very thin and crest-like between the posterior margins of the palatines but from there on abruptly diminishes in height and increases in width, and finally sheathes the entire ventral face of the presphenoid. It is deepest at the nasal passages.

Between the anterior margins of the palatines and the first two-rooted teeth, the maxillae are separated from each other by the vomer. In front of this bone the premaxillae form a wedge which increases in width anteriorly. The ventral surfaces of the maxillae are rather flat between the rows of two-rooted teeth, and are marked by shallow longitudinal grooves. The base of the rostrum is characterized by a well-marked constriction which commences at the postero-external angles of the alveoli for the next to the last molars. Posteriorly, the maxillae are overspread by the palatines.

An enlarged and thickened wedge like lachrymal is inserted between the supraorbital process of the frontal on the rear, and the horizontal plate of the maxilla and the jugal on the front. It extends inward beyond the internal wall of the infraorbital foramen, and apparently was in contact with the pterygoid. The position of the lachrymal on the ventral face of the skull is more in agreement with that of *Kogia* than any other cetacean known to the writer. In *Squalodon bariensis*[1] a splint-like process of the jugal extends backward from the maxillary notch to the antero-inferior margin of the zygomatic process of the squamosal. Anteriorly, the jugal in this fossil skull occupies the same relative position, but its posterior extension is missing on both sides.

The postorbital margins of the supraorbital processes of the frontal are rounded and their postero-external angles are not perfect. A narrow groove between the parietal and the presphenoid gives passage to the optic nerve from the interior of the braincase to the broad canal which traverses the middle of the supraorbital process. The lower portion of the narial passage is formed largely by the arching palatines. As the pterygoid is missing the side of the passage is not enclosed.

Teeth.—All six of the teeth which are in place in the maxillae have a well-marked cingulum. A distinctive feature is imparted to the cingulum by the closely approximated minute cusps which arise from it. Each of these teeth has two rather slender roots which are united at the base by a slender isthmus. The crown of the sixth two-rooted tooth is covered with rugose or striate enamel. The apex of the crown of the left tooth is missing, but there remain six well-defined cusps on the posterior, and four on the anterior cutting edge. The apex of the corresponding tooth on the right side is damaged to an even greater extent. Four cusps are present on the anterior cutting edge and an equal number on the posterior. The crown of the fifth two-rooted molar is higher than that of the sixth. There is a close agreement between the left and the right teeth in general features. Both have six well-defined cusps on the posterior cutting edge of which the two basal ones are rather minute, and four less prominent cusps on the anterior cutting edge. The fourth two-rooted teeth are so imperfect and fractured that description is impossible, but the sculpture of the enamel crown is the same as for the preceding.

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[1] Lortet, L., Note sur le Rhizoprion bariensis Jourdan, Archives du Museum d'histoire naturelle de Lyon, vol. 4, pl. 25 bis, 1887.

MEASUREMENTS OF THE SKULL

	mm.
Total length as preserved	371
Length of rostrum as preserved (from maxillary notch)	249
Greatest breadth of skull across supraorbital processes	183.3
Least breadth of cranium at intertemporal constriction (est.)	45
Greatest vertical height of skull (between frontals on vertex and crest of vomer)	105.7
Greatest vertical height of skull at base of rostrum (at level of maxillary notches)	86
Breadth of rostrum at maxillary notches	107
Breadth of rostrum at extremity	49
Total length of left maxilla as preserved	336.5
Greatest breadth of left maxilla (frontal plate)	59
Greatest breadth of left premaxilla at distal end	18.3
Greatest breadth of left premaxilla at proximal end	50
Least distance between inner margins of maxillae across nasals	44
Greatest breadth of exposed portion of paired frontals between the premaxillae on the vertex of the skull	38
Greatest length of exposed portion of right frontal on vertex of skull	44
Greatest antero-posterior length of left lachrymal	66.7
Greatest depth of lachrymal anteriorly	35
Greatest length of right nasal	34.7
Greatest length of left nasal	36.2
Greatest breadth of left nasal	15.4
Greatest breadth of presphenoid posterior to nares	35
Total length of vomer	301
Greatest length of left palatine	90.5
Greatest breadth of left palatine	53.7

MEASUREMENTS OF THE MOLARS

	Fourth upper molar Right	Fifth upper molar Right	Sixth upper molar Right	Fourth upper molar Left	Fifth upper molar Left	Sixth upper molar Left
Greatest length of crown	—	19.2	19.	18.6	19.	19.
Greatest breadth of crown	—	9.	8.7	—	8.4	8.5
Greatest height of crown (as preserved)	—	13.2	9+	—	13.3	11+

Xenorophus sloanii new genus and species. Type.

Dorsal view of skull. About ½ natural size. Fo. Max., maxillary foramen; Fr. frontal; Ju., jugal; La., lachrymal; Max., maxilla; Na., nasal; Pmx., premaxilla; V., vomer.

Xenorophus sloanii, new genus and species. Type.

Ventral view of skull. About ½ natural size. Ju., jugal; La., lachrymal; Max., maxilla; Pal., palatine; Pmx., premaxilla; S. or, pr. supraorbital process of frontal; V., vomer.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 76, NUMBER 8

ADDITIONAL DESIGNS ON PREHISTORIC MIMBRES POTTERY

BY

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(Publication 2748)

CITY OF WASHINGTON

PUBLISHED BY THE SMITHSONIAN INSTITUTION

JANUARY 22, 1924

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

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INTRODUCTION

In former papers[1] the author has tried to show, from archeological studies, that the prehistoric aborigines of the Mimbres Valley, New Mexico, developed a culture area differing from any other in the Southwest. The characters which more than any other distinguish this culture from others are the adornment of food bowls with realistic, sometimes composite, figures of men and animals, and the artistic character of the designs. Previously to the year 1914, few prehistoric Mimbres picture bowls had been published, but since that date, as shown in part by the literature,[1] many of these have been brought to light, and there are now several collections of size from this valley, which have characteristic realistic figures. Of late years there has been considerable activity in collecting prehistoric pottery in this area, and in May and June, 1923, the author revisited the Mimbres Valley to procure some of this new material for the U. S. National Museum, and the following paper is mainly devoted to descriptions of specimens purchased at that time from Mr. E. D. Osborn, who first called his attention to the pottery of the Mimbres Valley.

There are also considered in this article copies of photographs and drawings of other designs and specimens which could not be purchased for the U. S. National Museum.

The collections of Mimbres pottery that have been examined in the preparation of this article are: about 100 specimens from the Osborn collection, which were purchased; the collection owned by Mr. R. E. Eisele, of Fort Bayard, New Mexico; the collection made by Mrs. Watson, of Pinos Altos; and that of Mrs. Hulbert of the same city. Mr. and Mrs. Cosgrove allowed the author to inspect a fine collection carefully made by them at Treasure Hill (Whisky Creek) near Silver

[1] Archaeology of the Lower Mimbres Valley, New Mexico, Smithsonian Misc. Coll., Vol. 63, No. 10, 1914. Designs on Prehistoric Pottery from the Mimbres Valley, New Mexico, *ibid.*, Vol. 74, No. 6, 1923. Vide, *idem.* Vol. 65, No. 6, 1915; also Amer. Anth. (N. S.), Vol. XVIII, pp. 535-545, 1915.

City. This collection is particularly valuable as it was obtained from one ruin. The author also examined a few small collections, as that of Dr. Swope, previously considered, and a few specimens belonging to Mr. Thompson, of Deming.[1]

Although this article is limited to designs on pottery, which are by far the most distinguishing feature, the Mimbres culture may also be characterized by other artifacts which will be considered in a final report on Mimbres prehistory.

Mimbres pictures are painted on the interiors of food bowls and the exteriors of vases. These objects are mortuary and found under the floors of the rooms, the walls of which nowhere rise above the surface of the ground, but are readily observed as small piles of rock called Indian graves. The grave yards are situated along both banks of the Mimbres River and are almost in sight of each other. In its course after it emerges from the hills the Mimbres River sinks underground but flows onward, reappearing at times when the clay bed of the river rises to the surface. The ruins do not always follow the subterranean course but occur scattered over the plain.

Although the geographical extension or horizon of the Mimbres area, as indicated by its peculiar pottery, has not been carefully worked out it is practically limited to the Mimbres Valley, but not necessarily to the terraces along the river. There are sites with picture pottery on the eastern side of Cook's Peak, a prominent mountain belonging to the range that incloses the Mimbres basin on the east. Northward Mimbres pottery has been found over the continental divide in ruins on Sapillo Creek and tributaries of the Upper Gila. The western extension of the Mimbres pottery area is not known, but the ceramics rapidly change in character in this direction, merging into Gila Valley types.

While the designs figured and described in this paper enlarge our knowledge of the ancient Mimbreños they do not materially change conclusions already published. Before we can attempt any very extensive interpretations we sorely need more material; but with the information here published we may venture a few suggestions regarding the culture of the ancient Mimbres people. This knowledge, being wholly derived from archeological data, must from the nature of its source be tentative. We have no other way of revealing the manners and customs of this prehistoric race, as historical accounts are very

[1] The author takes this opportunity to thank all those who have aided him on his visits to the Mimbres, especially Mrs. Watson, Mrs. Hulbert, and Mr. Eisele, who have allowed him to photograph and publish specimens in their collections.

meager and no one has identified the survivors of these people. Archeology contributes knowledge of their life by means of objective material and for that material we must search among wrecks of their houses and the mortuary and other objects which are found in them or in their graves and refuse heaps.

No one has yet carefully excavated their buildings sufficiently to determine the form of their rooms, although fragments of walls have been brought to light. There are two types of mounds, differing in size and contents. One of these types, situated at the Gonzales Ranch, is lenticular in form, made up of adobe containing few stones. These mounds appear as low elevations rising but a few feet above the surrounding surface. The other type, which seems to belong to a later settlement, is indicated superficially by piles of stones formerly laid in adobe in walls of rudest masonry. These walls formed rooms united in rows or even inclosing square courts. In some places there appear on the surface circles of stones,[1] generally of small diameter, bearing outward resemblances to the tops of the bounding walls of buried ceremonial rooms or kivas. Circular kivas have not been found, up to the present, as far south as the Mimbres but a knowledge of their existence and structure would be of value in comparative studies. Subterranean walls extending far below the surface have been laid bare, and several of these have a fine plastered surface.[2] Little is known of the structure of the roofs as wooden beams have not yet been found. The floors are composed of hardened adobe, sometimes overlaid with flat stones. The dead were buried in the corners of the rooms below the floors, some with limbs extended, others flexed. The bowls that accompany the dead are variously placed, some being at the side of the dead, but now and then they were placed over the head like a cap. Mortuary bowls were deposited with the dead by the ancient pueblos, whose cemeteries are situated outside the walls of their villages. These clusters of stone houses are locally called Indian grave yards, and are generally situated on natural terraces a few feet above the river bed to avoid inundation, but are not confined to the banks of the river, often appearing miles

[1] Possibly ceremonial rooms. "Architecturally the prehistoric habitations of the Mimbres Valley represent an old house form widely distributed in the Pueblo region or that antedating the pueblo or terraced-house type before the kiva had developed."—Arch. Mimbres Valley, p. 52.

[2] Mr. Cosgrove (El Palacio, July 16, 1923) identifies two rectangular rooms excavated by him at "Treasure Hill" as kivas, and refers to ventilation in them. The author is unable to accept this identification without more knowledge than is now available of their structure.

away from springs, suggesting the puzzling question, "Where did they get water?" One of the largest of the ruins, situated on Montezuma Hill, in sight of the highway not far from the village of Pinos Altos, covers a high hill and consists of many clusters of rooms. In no instance is there evidence that the rooms of Mimbres houses were several stores high or terraced as in the pueblo region. Neither has excavation revealed buildings surrounded by a wall resembling compounds like Casa Grande in the Gila. The mounds of ruins are low, seldom if ever having walls projecting above ground.

The most instructive of the large Mimbres ruins, and one that has yielded many specimens, is called Old Town. This site gives every evidence that it was once a populous settlement. It is situated at the point where the Mimbres river leaves the mountains and enters Antelope Valley. Old Town is a typical Mimbres ruin but has been pretty well ransacked by pot-hunters, yielding some of the most interesting specimens from this valley.

REALISTIC DESIGNS ON POTTERY

The designs on Mimbres pottery are mainly painted on the inside of food bowls and naturally fall into three groups: (1) Realistic; (2) conventional; (3) geometric. The large majority are realistic figures of animals. There are several realistic birds' figures where wings or tail have become more or less conventionalized. The geometric figures either form a marginal decoration or cover the whole interior of the bowl. They often adorn the bodies of animals.

There is one interesting group of realistic designs that is unique in pueblo decoration, viz., parts of two animals united, forming a composite representation of some mythological personage.[1] In one or two instances human bodies have animal heads supposed to be masks.

The different designs collected in 1923 are considered in the following pages. The most exceptional figures are those of composite animals, one of which is shown in figure 1, drawn from a photograph. This bowl, owned by Mr. Eisele, was found by him on the Gonzales ranch. The main figure was evidently intended to represent a human being crouched in a sitting posture, annexed to which is apparently the body of a bird, as shown by tail feathers. The face of the human being is well made and the body wears a kilt of checkerboard design. There are two curved pointed horns on its head. The face is crossed

[1] In this connection see Tello, Las representaciones de los dioses en el arte antiguo peruano. Inca, Vol. 1, No. 1, January-March, 1923.

by a white band; body and limbs are black. The author believes that here we have a composition of human figure and the tail of a bird, quite different from any figure on any other piece of pottery known to him.

One of the most instructive pictures in the Eisele collection is the bowl shown in figure 2, upon which are represented three butterflies with outspread wings, two with extended and one with retracted probosces. Each butterfly has two wings around the edge of which are the customary dots which are almost universally found on butterfly figures from the Hopi to the Gila Valley. In the middle of this group stands a man who carries on his head a small vase which he holds in position. One of the butterflies, clinging to the elbow of the man by its feet, extends its proboscis as if to take the contents of the vase. The color of this vase is light cream and the figures are painted in brown merging into black. The ordinary symbol of the butterfly is, of course, triangular; but in this case we have this insect shown from one side, which is a very rare position in pueblo pictography.

The design on figure 3[1] is very intricate, consisting of two units, each twice represented at opposite ends of diameter of the bowl. These units may be called central and peripheral. The former represent two human beings facing in opposite directions and separated by geometrical figures. The arms in each case are raised above the head as if holding a burden. The face of one is white; the color of the body is black. The appendages are slim. The other or peripheral unit is thought to represent a bird. Each of the two representations of this unit has extended tail. The last joint of the legs and the attachment of the legs to the back suggests a grasshopper. This is one of the most complex of all the Mimbres figures, and probably illustrates some ancient myth of which there is no survival, as the aboriginal inhabitants of the Mimbres have either completely disappeared or, what is more likely, have been absorbed into other stocks.

Figure 4 represents a native drawing of a naked[2] human figure with a feather tied in his hair. He holds at arm's length, in both hands, an animal which resembles a snake. On first sight the impression would naturally be that this figure indicates that the prehistoric Mimbreños had some form of a snake dance, like that of the Hopi, or that this figure represents a shaman or snake charmer conjuring with a reptile. It calls to mind a figure holding a curved object which

[1] When not otherwise stated specimens here described are now in the collection of the U. S. National Museum, and were purchased from Mr. Osborn in 1923.

[2] Naked men's bodies and limbs are painted black.

might be either a rabbit stick or snake, shown in figure 5; but until we have more detailed material we cannot regard this as more than a suggestion. It does not, of course, follow, even if this man is carrying a snake, that there was an elaborate snake dance among the Mimbreños.

Figures of snakes are rare, but Mrs. Watson, of Pinos Altos, has a bowl with two coiled designs resembling snakes but without an accompanying human figure; the author has elsewhere[1] figured a horned snake from this region.

The posture of the well-drawn figure of a man in figure 6 (Eisele Collection) is peculiar. Arms and legs are extended and the upper part of the head and nose is black; cheeks white.

The two human beings shown in figure 7 are remarkable. They suggest a child riding on the back of his parent, holding on literally by the hair of his head. This interpretation does not explain the fish attached to the nose of the smaller figure, leading to the belief that there must be some unknown legend back of this figure. The fish has the two ventral fins and the two pectorals. There is also an anal fin but no dorsal. The fins that are represented are longer and more pointed than is usually the case; and the crescent that ordinarily represents the gill opening and operculum is missing, its place being occupied by an unusual black object depicted on a white ground.

The small figure is apparently clothed in one of those jacket-like garments worn by figures of hunters shown in a former article.[2] This garment is held in place by a woven belt whose ends appear in the figure, tied around the body. There is no indication of clothing on the larger figure, whose head, body, arms and legs are black, the customary color in representing nude figures. The attitude of the arms suggests an ancient Egyptian at prayer. The profiles of the faces in both figures have a certain likeness.

Whether figure 8 represents fishermen who have captured a large fish, some fish legend or a ceremony connected with fishing, is unknown, but each of the four participants has a line connected with the fish's mouth and above the group is an upright pole with feathers attached at intervals. Every man has a different attitude and the faces of all are painted white with black crowns. The cheeks are crossed with parallel lines which also extend lengthwise on the fish. The operculum

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[1] Archaeology of the Lower Mimbres Valley, Smithsonian Misc. Coll., Vol. 63, No. 10, fig. 28, 1914.

[2] Archaeology of the Lower Mimbres Valley, Smithsonian Misc. Coll., Vol. 63, No. 10, fig. 13, 1914.

is not crescentic as in most fishes but is indicated by a white line. The head, fins, and tail are black; ankles of all men are white in color.

In figure 9 a man holding a bow and arrow is shown; head and limbs are evident, but the bowl is so broken that other details do not appear.

The head of the animal represented in figure 10 resembles that of a carnivorous animal, as a mountain lion. The remarkable feature in this figure is the tail, which is very much thickened and elongated, bearing a terraced design on the surface and ending in a triangular tip. A chevron figure on the head of this animal has some resemblance to one on a serpent figured elsewhere.[1]

The design figured on the inside of the food bowl (fig. 11) represents a quadruped with a very long tail, curving over the back and ending in a white tip. Attention should be called to the fact that in this figure the anterior legs bend forward, and not backward, which is the general case in most quadrupeds. This animal is apparently walking on his tail and perhaps visualizes some ancient myth similar to one to which my attention has been called as existing among the Plains Indians.

The quadruped depicted in figure 12 evidently represents some carnivorous animal of the cat group, resembling somewhat a wolverine. The interior of the bowl was so much broken that only one figure remained, the duplication being restored.

Figure 13 is a figure of a mountain sheep or goat not unlike some other representations of the same animal elsewhere figured.

We have in figure 14 a representation of a mountain goat, the form and attitude of which is highly characteristic. In figure 15, which represents a mountain sheep, the differences are brought out.

Figure 16 represents a mountain lion but differs from any yet figured in the white line that extends from the ears to the throat. The tail in this figure is turned over the back—an almost universal position in pueblo pictures of the mountain lion.

Figure 17 is a negative picture, or one in white on a black background, representing a rabbit. The ears bear the customary black spots, and the eye is circular in form.

Figures 18, 19, each represent two rabbits painted black on a white ground. The body of one is marked with a longitudinal curved white band with black dots, the other with a checkerboard pattern. But few instances of rabbit pictures are known to me in which the side of the body is decorated with any figure.

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[1] This figure has, however, a cephalic horn which is absent in the design considered, which also has two ears.

In figure 20 we have representations of two animals, possibly mother and offspring, one large, one small, both of which have similar projecting jaws. The posterior end of the body of the smaller merges into a fish; the body and hind legs of a quadruped are replaced by the body and fins of a fish, two on the back (where there is never in other fishes more than one dorsal), and one anal fin.[1]

Figure 21 shows two hornless quadrupeds standing feet to feet on an ornamented base decorated with checkerboard design. The body of each bears an intricate cross design with stepped edges. The neck has white lines on three sides of a rectangle. Body black; eyes lozenge shaped; ears prominent; tail short, stumpy, marked with white lines.

Figure 22 represents some mythic animal with four legs, and a raised wing. The body is continued in a very unusual posterior appendage recalling a human leg. This specimen belongs to the Hulbert collection. The body is surrounded by a belt with two series of squares, alternating black and white. The mythologic conception in the mind of the painter of this design is a strange one, unlike any yet described in pueblo folk tales.

Figure 23 represents two figures with round heads, large white eyes and prominent lips. The figures of hands apparently are shown on the corners of the bodies. Legs well drawn and toes human in character. No suggestion is made regarding the identification of these figures.

Figure 24 is a negative picture of a flying creature like a bat[2] with large outspread wings, round head like that last mentioned, and prominent ears. This animal has a tail like that of a mouse outlined in white on a black ground.

Figure 25 shows two quadrupeds with short, stumpy legs, relatively large heads and small necks, with white bodies. No identification of these animals has been made and the details of the small drawings are very incomplete.

The peripheral parallel lines surrounding these figures are crossed by a zigzag line which follows the course of the inner cluster of encircling parallel lines making a singularly ornate and exceptional decoration.

[1] The frequent occurrence of fish designs on Mimbres picture pottery has led to a suggestion that we have evidence of a former life near more water than now flows in the Mimbres. But facts do not warrant the conclusion. The author has previously described a figure of a combined antelope and fish.

[2] The belief that this figure represents a flying mammal or bat, is based on the shape of the head and the absence of feathers.

Figure 26 belongs to the Eisele collection and was found in the same ruin as figure 1. It represents a wading bird (ibis ?) with correspondingly long legs and neck, along which are four small fishes. A short distance from its beak is another fish, apparently about to be devoured by the bird.

One of the instructive forms of composite animals is a figure resembling a bat seen laterally. It shows tail, fore and hind legs of a quadruped, and an appendage attached to the back as seen in figure 27. This appendage represents a wing or row of feathers, seven of which are rounded at the tips and 24 marked with dots at the distal end, and three have their extremities cut off straight, angular or more pointed than the other feathers. The snout of this animal closely resembles that of a bat and has teeth. Three arrows are shown as converging at the mouth as if talking to this animal. Altogether, this is one of the most exceptional forms of flying animals in the Eisele collection, and represents some ancient myth.[1]

As in collections previously described, avian figures predominate, but the few specimens here considered introduce one or two novel variations. The simplest form of bird figure in the collection made in 1923 is shown dorsally in figure 28. Here we have a form where wings, body, tail, and head are outlined with straight lines. The head is triangular, black in color, with two dotted eyes. The wings are also triangular and are crossed by parallel lines. The body is rectangular and the tail ends in two triangular black points. The peripheral zone of decoration of this vessel is peculiar and artistic, consisting of alternating zigzag and triangular lines, the character and shape of which are shown in the figure.

Figure 29 (Eisele collection) represents a quail with tufted head turned to one side, and peculiar wing feathers. The aborigines rarely represent a bird laterally with its head twisted back as gracefully as in this picture. The curved appendage to the eye recalls the club-shaped bodies so constantly occurring in Casas Grandes pottery. The wing feathers are of two varieties: one with rounded tips and dots; the other pointed, without dots. The wing is made conspicuous by being white in color while the body is black. The necklace is white.

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[1] It suggests a quadruped with an extended wing of a bird. The situation of the arrows is suggestive. In several Hopi legends there are accounts of how a supernatural being shot arrows into the sky, which talked with a mythological personage and then voluntarily flew back to the sender. One of these talking arrows was noted in the legend of the Snake people. Snake Ceremonials at Walpi, Journ. Amer. Arch. and Eth., Vol. IV, 1894.

The bird in figure 30 has widely extended wings of triangular shape, the feathers being represented by dentations on the lower side; the tail feathers have characteristic white tips. The body is globular, without legs. There are parallel lines on the head resembling a tuft of feathers. The body decoration is a square enclosing three parallel concentric lines and a white interior. The head is turned to one side, but the tail is shown from above.

Figures 31 (Eisele collection), and 32 are representations of a similar bird. The extended wings of figure 31 are crescentic and bear midway three parallel white lines. Along the lower edge of each wing are clubshaped feathers. The head and tail are seen dorsally. The legs are abnormally extended, one on each side. The irregular design just below the neck is a perforation made when the bowl was " killed."

In figure 33 we see a well drawn representation of a turkey cock, showing the tail feathers twisted vertically out of perspective. The figure below on which it stands is a turkey hen. We have here both sexes of the turkey. It will be noted that the body of the cock is not perfectly square but the surrounding lines are slightly bent or curved, imparting some grace to an otherwise stiff figure.

As has been stated elsewhere negative pictures of animals or geometric designs occur on both Mimbres and Casas Grandes pottery. In these figures the animal is not drawn but a background is painted in such a way that a white figure is represented. In certain Mimbres designs within the profile of the white or rectangular field is a picture in black. A figure of a human being or animal drawn inside the negative of the same is exceptional in pueblo ceramic decoration. An example of this form of design is shown in figure 34.

The bird represented in figure 34 is double headed and is one of those very exceptional figures in which we have a negative picture overlaid with a positive so that the latter seems to be rimmed with a white border. The body is rectangular, covered by a checkerboard design of small black and white lozenge-shaped figures. The two wings are dentated along their borders; legs short, without claws. The two round heads with short beaks face in opposite directions, and curved appendages recall feathers.

Remove the picture in black from its setting or background and the negative picture of a bird still remains, or a white figure with black background. There are one or two other examples of similar overlaid pictures in Mimbres picture bowls.[1]

[1] Designs on Prehistoric Pottery from the Mimbres Valley, Smithsonian Misc. Coll., Vol. 74, No. 6, fig. 10, 1923.

A well drawn bird figure shown in figure 35 is represented on the right side. Unlike most of the Mimbres birds its beak is short and the legs are small, placed far back on the body. Almost all the body is covered by a checkerboard design composed of alternate squares, white and black in color. The extended primary and secondary feathers of the wing are clearly seen. The tail is quite unlike that of other birds, more like that of some quadruped. The geometrical marking on the body under the extended wing is exceptional.

The design on the bowl shown in figure 36 is an unknown bird whose neck is ornamented with a number of dotted squares arranged in a zigzag figure recalling the design on the head of a Horned Serpent shown elsewhere. The association of the checkerboard figure on the sun and serpent symbol is highly suggestive. The puncture in the middle of this bowl hides the figure on the body which is indicated by ends of white lines. This bird stands above an implement of unknown use.

Figures 36*a* to 36*f* represent the different forms of this implement which is several times figured with the realistic designs from the Mimbres. The exact use of these objects is not known but it has been conjectured that they were knives, batons, or other stone objects, with handles. The simplest form is shown in figure 36*a* and consists of an elongated blade attached to a handle. This blade has zigzag markings which Mr. De Lancey Gill has suggested represent chipping of a stone implement ("sword").

Figures 36*b* and 36*c* are aberrant forms of an implement that may have been used for defense, the same shown under a bird in figure 36. Figure 36*f* resembles in some respects a stone spear point.

Figure 36*a* introduces a figure of a circular body between the handle and the shaft, and two crescentic extensions between the handle and the blade.

Figure 36*e* would seem to be analogous to the group of implements above although it wants the handle so conspicuous in the three preceding figures. It has a circular extremity around which are a number of small semicircles. This object was held in the hand of a quadruped, whereas, the other objects were associated with birds.

In figure 36*f*, where two of these objects are represented on the same bowl, we have, in addition to the handle, radiating lines at the point of attachment of the shaft and handle.

The middle of this bowl has been punctured in "killing," thus rendering it impossible to discover whether an arm and leg is drawn on each side.

As the use of the objects which these figures represent is purely conjectural it is much to be hoped that other bowls on which they may be figured will later be brought to light for examination.

The present figure (fig. 37) is from the original now in the U. S. National Museum, and differs from the former illustration[1] in the tail feathers which are unique. Each of the six tail feathers bifurcates into two parallel lines as here shown (fig. 37). The wing is highly symbolic; its central part in the original has a brown color which is here incorrectly indicated by parallel lines resembling hachures elsewhere shown. We have only one-half of this bowl, but there were undoubtedly two parrots on it when complete. The triangular object in front of the parrot is connected in some way with the "sword" elsewhere considered.

Portions of a head and tail of an animal are shown in figure 38. Enough is preserved to indicate that they are parts of a bird figure carrying a twig of leaves or feathers in the mouth. The middle of the bowl is too much broken to enable one to determine the shape of the body, wings, and the remainder of the design.

The mouth of figure 39 has teeth unlike any genus of living bird and the tail resembles that of a fish more than any other animal. The specimen is owned by Mr. Eisele, of Fort Bayard. The head bears two horns that remind one of some species of Cervidae, but the body and wings are strictly avian. The correlation of a long neck and legs exists in this picture.

Figure 40 shows two negative designs, that above representing a rabbit and the one below a highly conventionalized bird. These two figures are separated by a band consisting of several parallel lines black and white alternating. The original is in the Hulbert collection at Pinos Altos.

Figure 41 is a well drawn bird from the Eisele collection as seen from the side. This bird shows a tail prolonged at the two corners into pointed feathers and is the only bird design that has this characteristic.

Figure 42 represents a man herding a turkey whose globular body is different from that of any turkey yet described. The original specimen is in the Watson collection at Pinos Altos.

Two designs of figure 43 in Mrs. Watson's collection are supposed to represent serpents, but their identification is doubtful. They are comparable with the so-called serpents held by the priests shown in figures 4 and 5.

[1] Designs on Prehistoric Pottery from the Mimbres Valley, fig. 46. Fig. 6 in this article is a female figure with a basket on her back in which are twins, each with a sun symbol.

Figure 44 is the dorsal view of a lizard. The design on the margin of this bowl appears never to have been completed but consists of triangles, five of which are simply outlines; the remainder filled in with solid black.

The surface of the food bowl shown in figure 45 is decorated with a picture of a turtle crowded into the whole interior surface of the bowl. The body of this turtle is crossed by a number of parallel longitudinal lines and on each side of it are two curved bands with dentations on one side. The hind legs have no indications of feet. On each side of a pointed tail and in a corresponding position to the head there are depicted angular extensions of the rim, black in color, the shapes of which can be seen in the figure (45).

The head of figure 46 also resembles that of a turtle but the fragments of the bowl on which the body was drawn are missing. The fore and hind legs and tail are represented by triangles painted solid black.

Figure 47 represents a turtle with outstretched legs, triangular head and a single eye. It is surrounded by four white scrolls.

Figure 48 has fragmentary parts of two lizards arranged side by side.

Figure 49 represents a turtle with four claws; the tail and head shown on the periphery of the carapace. The back is covered with a rectangular figure with concentric quadrangles.

It is interesting to notice how often[1] the fish was used by the prehistoric aborigines of the Mimbres Valley in decorating the inside surface of their food bowls. The main differences in the different fishes are specific or indicated by the geometric figures on their bodies or in the shape and number of their fins. The body of the fish shown in figure 50 is decorated with a plaid, rarely used but not unknown as a geometric ornament.

Animals with their mouths approximated are sometimes found on Mimbres ware and it is suggested that the intention was to represent these two animals as talking to each other. In figure 51 we have a common example of this usage in Mimbres pictography, namely, a bird and fish with mouths approximated.

Figure 52 represents a fish, the body of which is covered by a checkerboard design of alternating black and white squares. In other respects this figure is not exceptional, similar fishes having been often

[1] Very few fishes are depicted on prehistoric pueblo pottery of other areas so far as is known to the author.

figured, but the arrangement of the gill opening is unusual and the anterior end of the body is differently marked from others that the author has seen.

The bowl, the design on which is shown in figure 53, was broken when found, rendering the relationship of the two animals and the accompanying object painted on it more or less doubtful, but parts of a fish figure and of an antelope are recognizable. The highly instructive original of this picture is owned by Mrs. Watson. Apparently this is not a composite of an antelope and fish but the former stands in front of the latter. The author has no theory to suggest regarding an identification of the object on which the hind legs of the antelope rests.

The animal pictured in figure 54 is called the "vinagaroon" and belongs to the Arachnida, or spider group, differing from insects in having four pairs of legs instead of three. Two representations of this animal are known to the author but the greater part of one figure is illegible.

Figure 55 represents some insect, as a grasshopper, the surface of the body of which is covered with a checkerboard pattern.

The animal shown in figure 56 has three legs on one side of the body, recalling an insect. It has antennæ and head like those of the same group of animals; but the body is far from realistic, recalling a turtle. This may be one of the composite animals of which the author has already spoken, as its identification as one animal is difficult.

The design on figure 57 represents the same animal as figure 56, but with minor differences. Legs are absent in this figure and its body instead of being decorated with a checkerboard pattern has wineglass and other figures in white outlines on a black ground. In figure 57 the semicircular design corresponding to the curvature of the body is black; its middle is occupied by a semicircle with hachures and saw-toothed straight edge.

The author is unable to identify the insect pictured in figure 58. It has certain anatomical likenesses to the ant lion but the head is somewhat exceptional. The original figure shows a possible composite animal, but the relationship of it is unknown. The original is owned by Mrs. Hulbert, of Pinos Altos.

Figure 59 is probably a mythological conception, the identification of which is at the present time conjectural. In form the main design is a prominent circle with triangular extensions suggesting a sun symbol and two eyes like those of a mask. This disk is supported on two appendages resembling legs. An elbow-shaped organ hangs between these legs, and the region of the face below the eyes is covered by a chevron-shaped zone of alternate black and white squares forming a checkerboard decoration reminding one of the figure of the sun elsewhere shown. It is possible that this is a representation of some mythological being, or symbol associated with sun worship; but too little is known of the Mimbreño mythology to properly identify it.

GEOMETRICAL DESIGNS

The Mimbres geometrical designs are quite unlike those described from pueblo areas. Several geometric designs are negative figures or white designs brought out by black backgrounds. The most abundant geometric figures are the interlocking slanting terraces, one covered with hachure, the other plain black. In all the figures rectilinear lines predominate and zigzags are the most pronounced. It is wonderful how many different designs can be produced by a modification of the two interlocking terraces, parallel lines and cruciform figures. All geometric designs are limited to the inside surface of mortuary bowls, the exterior being destitute of decoration. There are no broken encircling lines.

The characteristic geometrical patterns of the Mimbres ware, on account of their strictly American character no less than their great artistic beauty, are particularly good as patterns for decoration of fabrics and specialists have already begun working on them with this thought in mind. They are as unlike those of prehistoric pottery from other pueblo areas as are the various realistic designs already considered. Their significance cannot be determined—a condition true of most pueblo geometric figures—but irrespective of that they are of the utmost importance in determining by comparative methods of the relations of the pottery and hence the relation of subcultures of our Southwest which is the home of the pueblos. The general characters of the geometrical patterns may be seen in figures 60 *et seq.*, no two of which are identical. It will be seen on examination of these figures that the majority are linear designs with now and then curved lines. Among other figures may be identified the cross, stars, broad arrow, squares, triangles, checkerboard and other figures.

The designs are simple, either covering the whole interior surface of the food bowl or confined to the periphery leaving a central circular, rectangular or other formed area without decoration.

The design on figure 61 represents a four-pointed star outlined in pure black and filled with a hachure. Its center is occupied by a geometric figure with a number of concentric smaller rectangles

A five-pointed star has not yet been found in Mimbres designs and the star made up of four blocks of solid black with a white center so common on Sikyatki[1] (a Hopi ruin) and other Hopi pottery is likewise absent in Mimbres ware.

In figure 62 we also have a representation of a star verging into a cross in which the arms are not pointed but cut off at right angles. The design in figure 63 is cruciform with suggestions of a swastica. The arms are prolonged into needle-like points; on one side of each arm there are three serrations with notched edges. This unique form of cross the author does not find duplicated in prehistoric pueblo pottery and is peculiar to the Mimbres.

The cross-shaped figure forming the design (fig. 64) has three arms and a central circular area; the intervals between the arms being filled in with parallel lines or hachures and dots. This figure, like the preceding, is peculiar to the Mimbres ceramic area.

There is very little duplication of geometric designs in the collection. The design of figure 65 is painted red and consists of three arms, each formed of three parallel lines extending from a circular center to the periphery. The three areas between these groups of lines are filled in with zigzag white figures ending in interlocked spirals, a unique form of decoration.

In figure 66 we have the negative picture of a three-lobed design bordered with dentations, the triangular intervals being filled in with solid black.

The beautiful design shown in figure 67 can best be appreciated by an examination of the illustration. Cross hatching introduced in the two opposite units is a new feature in Mimbres geometrical designs and is exceptionally striking.

There are six white bordered arrows in figure 68 alternating with three rectangles with hachures and three in white forming an attractive design exceptional among pueblo decorations.

Figure 69 is an artistic design with four rectangular figures on a black ground alternating with which are eight small white circles each with a cross in black at its center.

Figure 70 is largely made up of negative designs artistically arranged with hachures, dual terraced figures forming a combination of a unique character in pueblo designs.

Figures 71 and 72, hitherto undescribed geometrical decorations on pueblo pottery, are artistic and so far as known characteristic of the Mimbres. Although the various geometrical designs on Mimbres pottery differ greatly they have a general similarity.

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[1] Vide 17th Ann. Rep. Bureau of American Ethnology.

Figures 73 and 74 are characteristic designs not found among pueblos.

The design on figure 75 is an intricate serrate figure surrounding a central circle that is devoid of decoration. The two regions of the zone about the central figure are different; on one side we have three points of a star; on the other bars and hachures.

The design shown in figure 76 is a central white circular zone with projecting points of an irregular star around which is a meander of white lines with black background, in four zones, each zone remotely like the others.

Figure 77 has zigzag lines surrounding a central circle without decoration. There are rain-cloud designs which can best be seen by examining the figure.

In figures 78 the design is composed of zigzag and other figures surrounding a central undecorated circle.

Figure 79 shows a design on a black background made up of zigzags, rectangles, and hachured triangles surrounding a central undecorated zone.

Figure 80 recalls pueblo designs but is strictly characteristic of the Mimbres.

Figure 81 is an unusual geometric pattern in which hachures and white zigzag lines predominate.

In figure 82, representing a design from the Black Mountain ruin, we notice the main differences between Gila and Mimbres designs. This bowl is made of red ware and has a yellow interior on which are painted a solid black circular rim and white squares with black dots.

In order to show how much the designs on Gila Valley pottery differ from those of the Mimbres Valley the author has introduced figure 82 from the Black Mountain ruin not far from Deming. This ruin was settled by colonists from the Gila Valley and in its mounds are also found other specimens of Gila Valley pottery as well as that characteristic of Casas Grandes, specimens of which are also shown in subsequent figures.

The design (fig. 83) consists of a number of zigzag bands radiating from the center.

Each of the designs (fig. 84) can be reduced to a quadrangular body the margins of which have rows of triangles.

The design on figure 85 is stellate, in which the white is brought out into a negative picture by a decorative black base. The design is not symmetrical and is characteristic.

In figure 86 we have represented a design made of white areas as in figure 85 forming a cross with four arms. Few specimens of this design have been found in the Mimbres Valley.

The design (fig. 87) has elements of figure 86 and that shown in figure 88 has an hourglass center. The last designs are unique, never found in pueblo decorations.

Figure 90 shows a unique design from a Mimbres bowl composed of two units: one, white bars interlocking with parallel black lines; the other, white zigzags on a black base.

The design on the food bowl shown in figure 91 is a cross formed of white bands, and parallel lines surrounded by encircling lines and hachures arranged in groups.

The design on figure 92 may be reduced to two rings surrounding a black central circular region. These two rings are made up of alternating white triangles on a black ground; but these triangles do not correspond, to form rectangles, as one would expect; the triangles in the interior zone are more pointed than those of the exterior zone. There seems to be no indication, however, that in making these double designs a pattern was used, and the whole design affords evidences of having been drawn free-hand.

In figure 93 we have a design depicted on a flat circular clay disk, in Mrs. Watson's collection, slightly curved on one face and flat on the other. The design is restricted to the curved surface; the flat side being undecorated. The use of this object is unknown, but it has a likeness to one shown in profile in a previously published figure where three men engaged in a game of chance are represented and the stake is a bunch of arrows in a basket.

Figure 94 shows a design of intricate character in which are introduced a central undecorated area surrounded by a rectangular figure with radiating extensions recalling figure 63. The peripheral portion of this design is quite different from those previously described in the so-called friendship curve, a pueblo feature repeatedly found on pictographs and pottery designs. It also occurs in various modifications of Mimbres pottery.

Figures 95 and 96 are simple designs that need no description and can be readily understood by examination of the illustrations. The element of artistic beauty in figure 95 that separates it from the majority of other designs of the same general nature is a series of dotted lines forming a tracery passing over the zone of parallel lines surrounding the central figure.

Figure 97 shows two effigy jars from the Mimbres Valley which are instructive as indicating the geographical distribution of this form. In the Casas Grandes pottery, where these effigy jars are much more numerous and complicated, we have a very large relative number of similar forms, some of which have been modified into human figures. In the Mimbres, on the contrary, objects of this kind are quite rare. The designs on the two here figured strictly belong to the Mimbres group.

In figure 98 we have still another of these effigy jars, which, however, differs from those spoken of above in that a handle is absent. The form of these jars suggests a conventionalized bird, the conventionalized designs on the body representing wings; the eyes and mouth are rudely indicated by circles. The remaining designs on figure 99 are representations of a mountain sheep, and on figure 100, what appears to be a composite animal having a tail of a bird and the limbs, thorax, body, and head of an insect.

The last figure (fig. 101) represents four rude undecorated vases belonging to the coiled variety of pottery, evidently cooking vessels, one of which has a handle. This type of pottery, found throughout the Mimbres Valley, recalls the archaic types recorded from the pueblo region but is crude in comparison with them. It resembles somewhat prepuebloan types from northern New Mexico and Colorado, but the fine corrugated and coiled ware of the North is thinner and shows greater technique and variety than that either of the Mimbres or Casas Grandes in Chihuahua.

Geometric decorations are generally arranged on bowls either in two or four; sometimes in three, but very rarely five and higher numbers. When the unit design is doubled the two units are placed diametrically opposite on the bowl. Decoration is always absent on the exteriors of the food bowls. It will be noticed in a consideration of dual designs in the series that the repetition of the same unit is painted freehand; no pattern or stamp was used and the unit pattern when repeated varies somewhat in execution. Evidently the potter held the object in her hand and painted by the eye, arranging the figures in such a way that the spaces might be filled by the pictures. A modification of the shape of the figure to conform with the area to be covered was not uncommon. The lines are sometimes so fine that we can hardly suppose the chewed end of a yucca stick was used as a brush as is generally the case among the Hopi.

COMPOSITE DESIGNS

The composite pictures are representations of two animals combined. The custom of uniting different animals as a unit is sometimes found among the more advanced tribes of Mexico and Central America, but is rare or unknown among the North American Indians. As examples of these composite pictures may be mentioned quadrupeds represented with a human head and nondescript animals with the body of an antelope and tail of a fish, or tails of twin fishes added to a turtle body. These composite pictures illustrate to the Indian mind their folk-lore or mythology and may represent mythological beings or legends now forgotten which were current at the time they were made. It may be possible by renewed research to find survivals of these stories in the folk-tales of kindred peoples and thus determine what personages these composites were intended to represent; but at present we can do no more than recognize that the Mimbres Valley pottery bears evidences of a rich mythology or folk-lore that has disappeared. Fishes and quadrupeds are the most common of the composite forms.

Two of the best examples of a composite animal in the collection now being described are shown in figures 1 and 14; in figure 37 the wing and its feathers, also the tail feathers, are conventionalized, while the head and body of the bird are wonderfully realistic.

Attention may be called to the tendency to conventionalize certain organs, as wings and feathers of birds, even when the figure of the bird is realistic. This may be an index of the change from realism to symbolism which in Sikyatki pottery has gone so far as to reduce the whole figure to a symbol.

COMPARATIVE STUDY OF MIMBRES DESIGNS

Geographically the valley of the Mimbres lies between high lands on the east and north and the Casas Grandes Valley on the south. As the physiography of these neighboring areas is different and pottery designs unlike each other, it may be well to devote a few lines to comparative studies. The northern and western neighbors of the aborigines of the Mimbres were those of the Gila Valley and its tributaries; on the south the Mimbres Valley merges into that of northern Chihuahua. It is natural that the distribution of ancient pueblo and other pottery in our Southwest should follow rivers or streams of water whose banks are natural trails. The presence of water, also a desideratum for an agricultural population, may be considered in a general treatment of migration of people.

The geographical location of tributaries of four streams of constant water, the Gila, the Rio Grande, the Little Colorado and the San Juan, played an important part in migration. The Mimbres not being connected with these rivers or their drainage areas, being in a way isolated, we may expect, *a priori,* that its pottery was little modified by that of these other drainage areas. The Rio Grande river in the latitude of Deming to the Gulf of Mexico is singularly free from tributaries, especially on the right bank, and there are no river routes for interchange of prehistoric people. Higher up we find pueblos on this river still inhabited. The Gila river also has few tributaries in its lower course and few ruins away from the river itself. It runs east and west; its sources and those of the Salt divided into numerous tributaries. In this country of the Upper Gila and Salt we find many ruins of several varieties. There are several northern tributaries where ruins are abundant and in the Upper Gila there are many tributaries and many ruins among the canyons of the sources of this river. Throughout its whole course from source to the Gila Bend there are many ruins. The northern tributaries overflowed their population beyond the Mogollon into the Valley of the Little Colorado as far north as the Hopi, Zuñi, *et alii.* This wide north-south distribution of Gila Valley pottery is due to the direction of the flow of the many tributaries of these rivers.

The main tributaries of the San Juan on the left or south bank were also significant in the direction of human migrations. The general trend of migration is south from this river and the ruins are more abundant near the sources and along tributaries. The isolated Mimbres Valley migrations had very little effect on the pottery designs of the aborigines of the San Juan.

There seems to be a consensus of opinion of the few ethnologists who have considered the Casas Grandes ceramic culture area that it is true puebloan, or that pottery likenesses are sufficient to place both in the same group. If we limit the term "true pueblo" to a type of sedentary culture[1] that developed in the northern part of New Mexico and Arizona and the southern part of Utah and Colorado, the differences are striking. The author believes there are so many features in the culture of the Gila that are different from the pueblo that in strict scientific usage it is better not to classify them in the same type.

It is believed that the Gila culture spread north over the Mogollon mountains into the Little Colorado valley and even north of that into

[1] Practically the so-called "Kiva culture" of the San Juan Valley, whose structural characteristics have been elsewhere pointed out.

the Hopi region where it mingled with the true pueblo, migrating southward, thus forming a mixed culture. In New Mexico the same thing happened; the pueblo element, originating in the north, extended as far south as Zuñi, in which are evidences of a mixture with the Gila culture. The ancient potters of the Upper Gila and Salt rivers left abundant pottery and there is enough material from which we can by comparison determine their relation to the people of the Lower Gila. They show the union of the true pueblo culture and that of the aborigines south of them, which did not greatly differ from the pueblos.

The pottery of the adjacent Gila-Salt area differs from that of the Mimbres in several characters. The designs on the interior are broad black rectangular lines on a gray surface, the outside of the bowl being red in color, whereas Mimbres ware is white with narrow black or red figures[1] on the inside of the bowls.

It is also pertinent to point out the differences between the pottery of the Mimbres Valley and that of northern Chihuahua (Casas Grandes region), which are significant. The available collections thus far made in these two regions afford differences in data; an examination of these collections shows that the specimens from the Mimbres are food bowls, while those from northern Chihuahua are vases. As a rule food bowls found in the latter region are small and deep, although sometimes large. They are decorated on the exterior, which is not the case in similar vessels from the Mimbres. About ten per cent of the Cases Grandes vases are effigies, while only a very small portion of the Mimbres vases can be so designated. In the Casas Grandes area are many polished black bowls like the so-called Santa Clara ware, but little black ware has thus far been found in the Mimbres. The same is true of undecorated red ware, which occurs in Chihuahua but is rare or absent in the Mimbres.

It is mainly in the decoration of pottery of the two areas that we find the greatest differences in the pottery. That from the Chihuahua mounds is more brilliant in color than any other in the Southwest; it is very smooth without superficial slip, in which it recalls old Hopi ware from the ruins of Sikyatki where the beautiful figures are also painted directly on the surface, not on a slip. Casas Grandes ware is a polychrome, or red and yellow on a gray-white ground. The ware

[1] Incidentally attention should be called to the uniform width of the encircling parallel lines and the boldness with which they are drawn in Mimbres ware. In the accompanying figures Mrs. Mullet has preserved that uniformity in breadth of line and distance apart. This fact is mentioned lest some critic may find too much regularity in the drawings.

from the Mimbres may be called the black and white, although many of the bowls are gray rather than white, and even pass into a red. The decorations of both Casas Grandes and Mimbres[1] food bowls are drawn in black and brown ranging into tan color, but it would appear at times as if this difference in coloration was due to unequal firing of the paint which is apparently some iron oxide. There are one or two polychrome bowls and one in which the figures are decidedly red. The change in color by exposure to the air in some specimens which were collected in 1914 is perceptible. But while the Mimbres pottery may be classified as black and white ware it differs from that found in cliff dwellings and other archaic ruins. The main differences are not so much in colors as in designs, which afford a clear idea of cultural differences. In other words, it is, of course, in the decorations that the main difference between the pottery from the two regions lies.

The animals represented on the Chihuahua (Casas Grandes) pottery are very few compared with those on Mimbres ware. Birds, snakes, a quadruped or two, the frog, and one or two others, embrace the main animal designs on the southern pottery, while in the Mimbres the number of animals depicted in very much larger. A complete list of these would make a catalogue of some size, but a few of those animals not found on Casas Grandes ware might be mentioned. Among quadrupeds are the lion, deer, antelope, mountain sheep; several species of fishes; a large number of birds; many insects, as butterflies, dragon flies; scorpions, turtles, lizards, and various other animals. None of these are represented in relief, however, as is the case with animal forms on pottery from Casas Grandes, but are painted on a flat surface mainly on the inside of bowls. There is no area in the Southwest where the animals represented on pottery outnumber those of the Mimbres, nor any area where the aboriginal potters have left us such truthful realistic pictures of animals by which they were surrounded.

The representations of human beings in the Chihuahua ware are painted effigies; there are few representations, so far as known, of an effigy human being or one in relief on the pottery of the Mimbres. The author has seen no picture on Casas Grandes pottery in which men are represented as hunting, gaming, or engaged in any occupation.

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[1] The character of the design rather than the technique of the pottery distinguishes the two regions.

The geometrical designs as well as naturalistic representations of men or animals from Casas Grandes and the Mimbres have much in common but several differences. One of the most common of the geometrical decorations is the step figure divided into two halves separated by a zigzag band. This is almost universal throughout the pueblo area.[1] In the Casas Grandes ware one of these oppositely placed series of step figures is generally (not always) black and the other tan colored or red. The same design on the Mimbres ware has one series painted a solid black color and the other has hachure lines, a design which occurs all over the Southwest and which the Mimbres area shares with the Pueblo and the ruins in the valley of the Gila. This likeness suggests that the Mimbres ware is allied both to the puebloan and to that from Casas Grandes.

One important geometrical decoration of the Mimbres pottery consists of parallel lines. In their desire to decorate all portions of the object they have almost invariably filled in different geometrical outlines with hachure or cross hatching, checkerboard or other rectangular figures as suited the wish of the designer. Another favorite geometrical design is the cross of various kinds, among which the elaborate swastika may be mentioned. A rectangular design of frequent use throughout the Southwest is the compound triangle made up of two or more united triangles. This is a favorite decoration on the bodies of animals and has been variously interpreted. The triangle is the symbol of life, and the arrangement of several triangles may have some similar meaning. Similar triangles, double or single, appear on the walls of kivas or sacred rooms of cliff dwellings, in the houses and on the wedding blankets of the Hopi girls. Among the living Hopi a triangle is commonly said to represent the butterfly, a symbol of life or fertility.

Another favorite rectangular ornament is the checkerboard pattern, alternate clusters of black and white triangles or squares forming a very effective rectangular pattern. The checkerboard is very commonly associated with the sun but is also frequently found in the paintings of animal bodies.

The majority of geometrical figures are rectangular or triangular: Spirals, circles, and curved lines are very rare.

There is one geometric design which occurs almost universally in the pueblo area and while it suffers several modifications is essentially identical in widely separated geographical localities. This dec-

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[1] One of the strongest reasons advocated to include these areas among the pueblos.

oration may be called the "dual reversed stepped design." It is composed of two terraced figures so placed that their terraces interlock, leaving a zigzag line between them. This is particularly characteristic of black on white or gray ware which is most abundant on the oldest decorated pottery of the Southwest, but it also survived into modern times. In the Mimbres pottery as in other types it forms the most abundant form of geometric decoration. The two series of reversed terraces are different either in color or design. This is indicated in the Mimbres by solid black on one side and hachure or parallel lines on the opposite, while in the Casas Grandes pottery one series is solid black, the other red, hachure being exceptional; the terraces here, acute angled among the pueblos, become right angles as in Mesa Verde pueblos situated in both caves and open situations.

The presence of this "dual reversed stepped design" on the ancient decorated pottery of our Southwest in the judgment of some authors relegates both Mimbres and Casas Grandes pottery to the pueblo type. It suggests that the Mimbres pottery is old,[1] and the fact that it is so abundant on black and white ware, which is considered old, supports the same conclusion. There are several other characteristic pueblo designs on Mimbres pottery, as the interlocked spiral. They point to pueblo affinities.

The rectangle is found constantly on pueblo pottery; it is sometimes simply an outline but may be solid black or crossed by parallel lines which may be cross hatched and form a checkerboard pattern with or without dots. The edges of these rectangles may be dentated, serrated, or without ornament, simply plain. The rectangular figure, generally single but rarely double, is very common on animal designs.

The realistic figures on Mimbres and the symbolic figures on Sikyatki[2] ware have little in common; there are comparatively few realistic animal designs depicted on bowls from the latter ruin. It was the habit of the Sikyatki potters to decorate the outside of their food bowls as well as the interior with geometric figures, a habit rarely if ever practiced by the Mimbres potters. The highly conventionalized designs on the inside of Sikyatki food bowls were seldom

[1] The black and white ware found elsewhere in the Southwest shows very few realistic figures except in the Mimbres, but many simple geometric designs.

[2] 17th Annual Report, Bureau of American Ethnology, Pl. CXXI. While comparative studies bearing on the relation of Sikyatki pottery are not wholly satisfactory it has seemed to the author that the affiliations of Awatobi designs with those of Sikyatki are not as close as he thought a quarter of a century ago. Awatobi pottery is nearer to that of the Little Colorado than is Sikyatki, and this is also the teaching of tradition.

accompanied with geometrical figures. Negative pictures, so common on the Mimbres ware, are not found on ancient Hopi (Sikyatki) ceramics. The great difference between ancient Mimbres and Hopi designs is that the former are realistic[1]; the latter conventional and limited to a few forms; no fishes, turtles, or deer appear on Sikyatki ware because aquatic animals were absent from their water course. Among the cliff houses we find mountain sheep represented realistically as pictographs. The ceramic art of Sikyatki reflects a waterless desert, but the Mimbreños lived in a valley where water, although small in quantity, was perennial.

The "killing" of mortuary bowls before they were buried is almost universal in Mimbres ware. The bowls were almost without exception perforated artificially. Sometimes several perforations were made and in one instance three of these holes were arranged in such a way as to suggest a mask with the mouth and eyes of a human face. Sikyatki pottery was never perforated and "killing" mortuary objects was almost wholly unknown. There are no reliable evidences that the San Juan cliff dwellers killed their mortuary pottery. The potters of the Gila killed their mortuary vessels as did also certain of their descendants.

The Mimbres pottery is distinguished from that of Casas Grandes by significant conventionalized designs. The "club-like" ornament, so conspicuous a negative design on Casas Grandes decoration, is practically absent in the Mimbres area. This ornament can generally be reduced to bird heads, feathers, or even bird bodies, and is generally introduced to fill in triangles where the background is solid black. Whereas bird figures on Casas Grandes ceramics like the "club-like" figures are almost invariably negative or white on black background, only a few negative pictures of birds are found on Mimbres ware, but instead birds are black or red painted on a white ground; we have no human beings, fishes, rabbits and other animals in white on black in Mimbres ware. This is one of the several differences between the pictured pottery of the two culture areas. Although bird figures differ there is a similarity in the form of feathers when used as an individual decorative element in the two regions.

We can say that the remarkable development of realistic designs in the Mimbres area is local, but that the designs are related to the pueblo and have affinities on one side to the Gila and on the other to the Casas Grandes, but on the whole the culture was self centered

[1]At Sikyatki we find few realistic and many symbolic and geometric designs; in the Mimbres many realistic, few symbolic and many geometric.

and unique. The interlocked terraced figures and spirals it shares with the pueblo may be a survival of a pueblo relationship and may be an evidence of a remote kinship, but in the Mimbres environment the designs have become wholly unlike the northern relatives.

RELATIVE AGE OF MIMBRES POTTERY

The age of the Mimbres Pottery is unknown save that it antedates the historical epoch. The method of determining its age by the stratification of shards in refuse heaps has not been found feasible in this region, mainly because deep refuse heaps have not yet been discovered. The small size of those that are known indicates a rather short occupation and although a few different kinds of pottery occur they have not yet been arranged in an evolutionary series. It is doubtful whether or not all types were synchronous with the picture bowls. Probably when the valley was first peopled the colonists came from areas beyond the mountains and the production of realistic figures developed after they had inhabited the Mimbres Valley for some time.[1]

The fact that these designs are highly realistic or specialized does not, in the author's judgment, mean that the culture which they express was necessarily late in development. What few facts we have point to limited residence in an isolated valley.

The potters who painted the designs on Mimbres ware were contemporary with those who decorated the beautiful pottery of northern Chihuahua and that of the Gila compounds as indicated by the presence of shards or even complete specimens from these regions. The transfer was either by traders or possibly by clans or colonists seeking new homes, which appears to account for the alien ware at Black Mountain ruin.

While the penetration of the Casas Grandes type of pottery into the Mimbres Valley, either through trade or otherwise, is indicated by this ceramic distribution, we have no evidence of a counter migration or that Mimbres types or styles of design migrated south across the Mexican border. We have large collections of Casas Grandes ware but in none of them are true Mimbres picture bowls.

The great abundance of designs and the absence of conventionalism is interpreted to mean that pottery making in the Mimbres was not

[1] Unfortunately the individual ruins from which most of the specimens here considered have been taken are not definitely known. There is, however, no evidence that there is any great difference in age between the various ruins along the Mimbres.

limited to a few individuals as among the Hopi. Many Mimbres women were potters and there was more individuality in the designs they used. Among the ancient Hopi (Sikyatki) pottery designs show a more crystallized conventional art.

It is not possible in the present state of our knowledge to determine the date when the prehistoric Mimbreños disappeared or possibly were merged into the Apache of the same time, but it appears that they were contemporaneous with the prehistoric population of the Gila and the Casas Grandes.

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Mullett

MIMBRES FOOD BOWLS.

1. Human being with horns.
2. Man and three butterflies.
3. Two human beings and two animals.
4. Man with serpent.
5. Man with snake.
6. Seated man.

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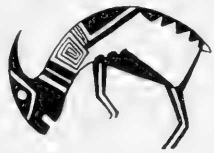
Mullett

MIMBRES FOOD BOWLS.

7. Two human figures and a fish.
8. Four men and a fish.
9. Man with bow and arrow.
10. Quadruped with large tail.
11. Unidentified quadruped.
12. Two mountain lions.

13



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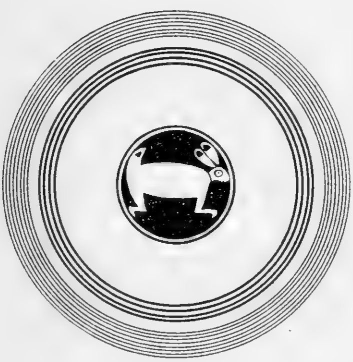

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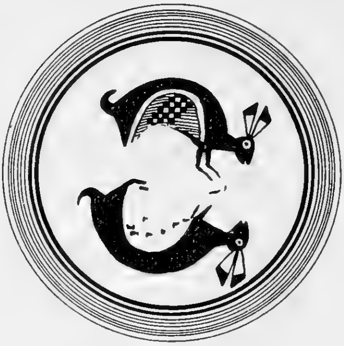
Mullett

MIMBRES FOOD BOWLS.

13. Mountain sheep.
14. Mountain goat.
15. Mountain sheep.
16. Mountain lion.
17. Negative picture of rabbit.
18. Two rabbits.



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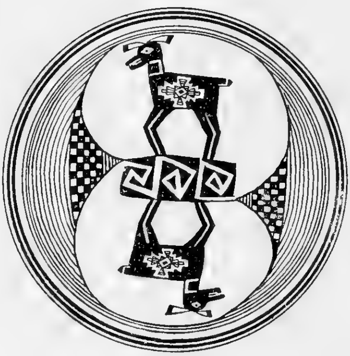

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Mullett

MIMBRES FOOD BOWLS.

19. Two rabbits.
20. Unidentified animals.
21. Two fawns.
22. Unidentified composite animal.
23. Two unidentified figures.
24. Negative picture of bat.

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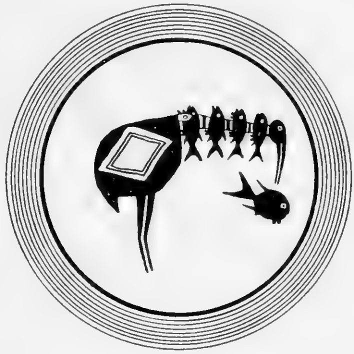

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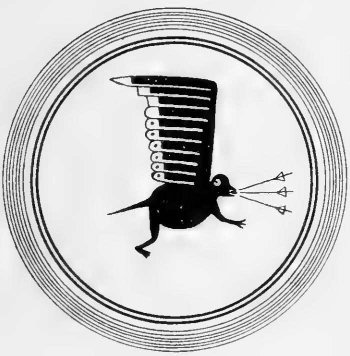

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Mullett

MIMBRES FOOD BOWLS.

25. Two quadrupeds.
26. Crane with five fishes.
27. Bat.
28. Cubist bird.
29. Unidentified bird.
30. Unidentified bird.

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Mullett

MIMBRES FOOD BOWLS.

31. Unidentified bird.
32. Unidentified bird.
33. Turkey cock and hen.
34. Bird with two heads.
35. Bird with elevated wing.
36. Bird with " sword."

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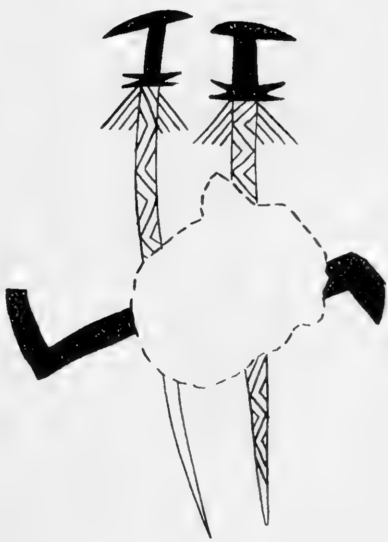
36c

36d

36e



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Mullett

UNIDENTIFIED OBJECTS FROM DIFFERENT FOOD BOWLS.

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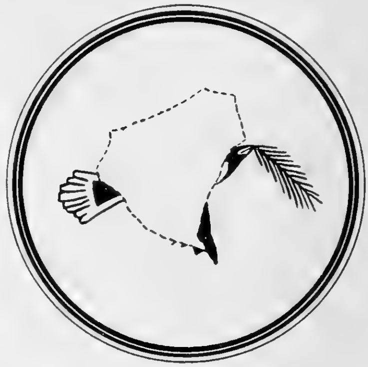

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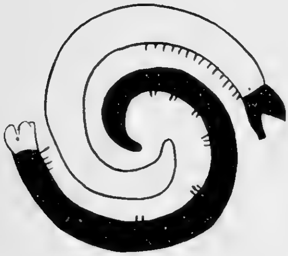
Mullett

MIMBRES FOOD BOWLS.

37. Parrot.
38. Dove (?) with object in beak.
39. Unidentified bird.
40. Negative pictures of rabbit and bird.
41. Unidentified bird.
42. Man herding turkey.



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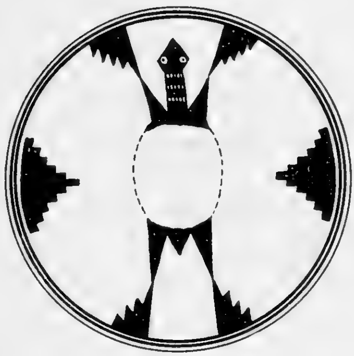

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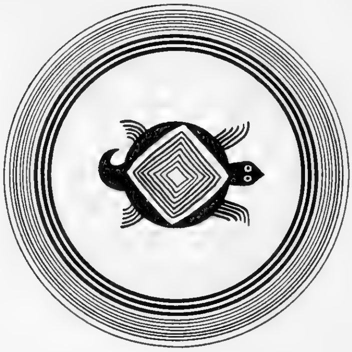
Mullett

MIMBRES FOOD BOWLS.

43. Two serpents.
44. Lizard.
45. Turtle.
46. Turtle.
47. Turtle.
48. Lizard.



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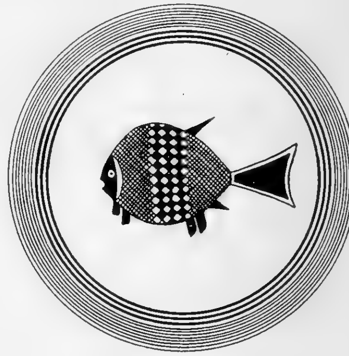

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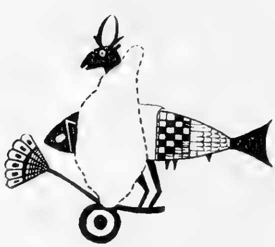

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Mullett

MIMBRES FOOD BOWLS.

49. Turtle.
50. Fish.
51. Bird and fish.
52. Fish.
53. Antelope, fish, and unknown object.
54. Arachnid.

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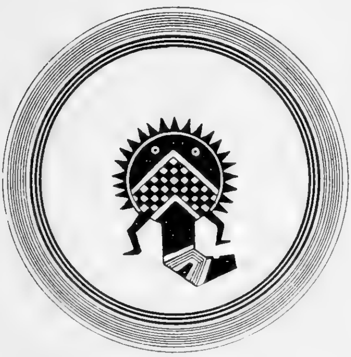

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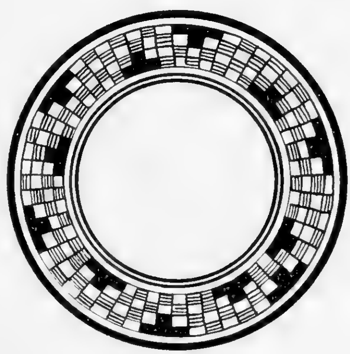

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Mullett

MIMBRES FOOD BOWLS.

55. Grasshopper.
56. Unidentified insect.
57. Unknown animal.
58. Unidentified insect.
59. Sun symbol.
60. Geometric design.

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Mullett

MIMBRES FOOD BOWLS.
Geometric Designs.

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Mullett

MIMBRES FOOD BOWLS.
Geometric Designs.

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Mullett

MIMBRES FOOD BOWLS.
Geometric Designs.

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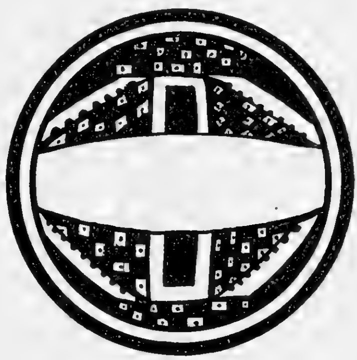

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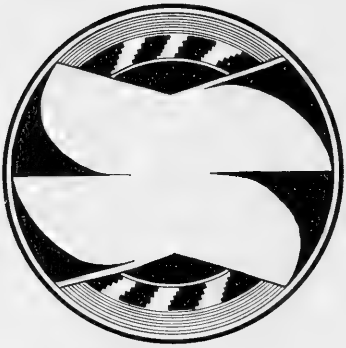
MIMBRES FOOD BOWLS.
Geometric Designs.



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Mullett

MIMBRES FOOD BOWLS.
Geometric Designs.

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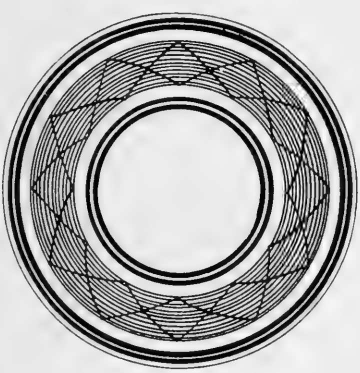

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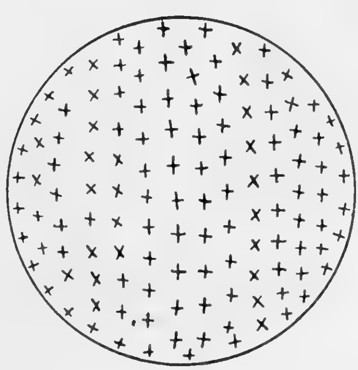

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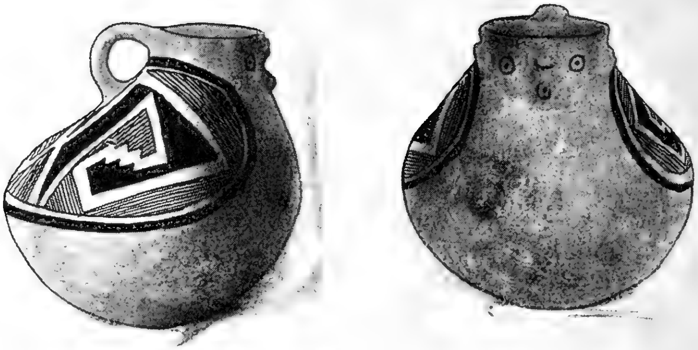
Mullett

MIMBRES FOOD BOWLS (FIG. 93, CLAY DISK).
Geometric Designs.



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99 **100** **98**

101

MIMBRES POTTERY.

97. Effigy vase (lateral and front view).
98. Effigy vase (lateral view).
99. Mountain sheep.
100. Unidentified insect.
101. Four rough corrugated jars.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 76, NUMBER 9

THE BRIGHTNESS OF LUNAR ECLIPSES 1860-1922

BY
WILLARD J. FISHER

(Publication 2751)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
FEBRUARY 18, 1924

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

THE BRIGHTNESS OF LUNAR ECLIPSES 1860–1922

By WILLARD J. FISHER

After Struve and Döllen had pointed out the advantages in observing occultations of faint stars during lunar total eclipses, and had circulated data facilitating the observations, there was an interest aroused among professional astronomers, who paid much attention to eclipse occultations for a considerable time; but only a few, as Flammarion, Barnard, M. Wolf, paid much regard to lunar eclipse phenomena in relation to the earth's atmosphere. The observation and description of the peculiarities of the earth's shadow, both before and after the occultation campaign, was largely left to amateurs. The organization and growth of great societies, like the Société Astronomique de France and the British Astronomical Association, have greatly increased the number of such observers and the volume of the recorded observations.

The present paper was undertaken with the expectation that in the mass of lunar eclipse literature there would be found evidence of a structure of the earth's shadow corresponding to the known dust layers of the atmosphere.[1] It was found that this object could not immediately be attained; rather, it seemed desirable first to study the brightness of recorded eclipses. This, to be sure, has been done by A. Danjon,[2] in papers in which, from a study of records going back to 1583, he has drawn the conclusion that there is a remarkable relation between the solar cycle and the brightness of lunar eclipses, mostly total. These papers have been destructively criticised by E. W. Maunder,[3] as using partial eclipses illegitimately, omitting details of evidence, such as criteria of brightness, durations, moon altitudes, magnitudes of eclipses, together with all references, making

[1] S. P. Langley, New York Tribune, Jan. 2, 1884; Knowledge, 5, pp. 80-81, 1884; Sidereal Messenger, 3, pp. 21-23, 1884; Nature, 29, p. 324, 1884; A vast dust envelope.

W. J. Humphreys, Bull. Mt. Weather Obs., 4, pp. 397-401, 1912; Dust layers in the atmosphere, and changes in the neutral points of sky polarization.

[2] A. Danjon, C. R., 171, pp. 1127-1129, 1207-1210, 1920; Bull. Soc. Astr. Fr., 35, pp. 261-265, 1921.

[3] E. W. Maunder, Jour. Brit. Astr. Assoc., 31, pp. 346-350, 1921.

no use of observed solar phenomena, and depending in all probability upon a false eclipse cycle.

This paper is not intended to traverse the extensive ground covered by Danjon; the period covered is 1860-1922, the former date having seemed natural, as about that time began the serious application of the spectroscope to astronomy, and also the publication, in the British Nautical Almanac, of more complete elements, convenient for making projections of eclipses.

It was soon obvious that spectroscopy has played but a limited part in the study of lunar eclipses. And so of instrumental photometry; determinations of the brightness of the eclipsed moon, except by rough comparison with stars, have been few. And so too of photography; while innumerable photographs of the eclipsed moon have been taken, apparently little use has been made of the plates. Almost all observations have been made with plain telescopes of all sizes, and with the naked eye; the brightness of the moon has seemed secondary to the moments of contact of the umbra-edge with the moon's limb and with various lunar objects. Seeliger [1] having shown that in all probability the apparent enlargement of the shadow detected by such observations has no objective importance, it is easy to agree with Crommelin that there is little use in piling up more of them.

Due to well-known optical principles, the telescope does not increase the brightness of any extended area, but really diminishes it. However, it is a fact of observation that during a lunar eclipse, objects which may be seen in the shadow with large telescopes are invisible with smaller. It is like the effect of night glasses; or like the fact that newspaper headlines in twilight can be read when the text below is a blurred mass. This suggests a criterion for the brightness of eclipses, usable when the observations are simply telescopic or with the naked eye.

On account of the mixed quality of the data a simple three-step scale of brightness has been adopted.

Grade 2.—When the naked eye sees the "spots" on the eclipsed moon, or the seas and other detail can be seen with hand instruments—opera-glasses, field-glasses, spy-glasses.

Grade 1.—When instruments of aperture of 2 inches up to 6 inches are necessary to show detail on the eclipsed surface. This includes ordinary stand-telescopes, porch telescopes, etc., and some fixed observatory telescopes.

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[1] H. Seeliger, Abh. Akad. Wiss. zu München, II Kl., 19 II, pp. 383-448, 1896-97; Die scheinbare Vergrösserung des Erdschattens bei Mondfinsternissen.

Grade 0.—When apertures of 6 inches or more are needed. This covers the larger part of fixed observatory instruments.

Table 1 shows the almanac date of the beginning of totality, the magnitude, the grade on the above scale, and the position of the terrestrial terminator (sunrise-sunset line) at mid-eclipse, for each lunar eclipse 1860-1922 for which data suitable to grade on the above scale have been found—68 eclipses in all. These facts for each eclipse are followed by the name of the observer, the place, a number in parenthesis referring to the list of references placed later in the article, and an abstract of the observations reported, beginning with the condition of the sky and the aperture of the telescope, or some statement about the means employed. Strength of twilight is as stated by the observer, or based on moon's altitude. Under each eclipse the observers are mostly arranged in an order indicated by the column headed Phase—Air Mass. The phases of an eclipse are indicated by

a, e, first and last external contacts.

b, d, first and last internal contacts (lacking in partial eclipses).

c, middle of the eclipse.

The relative air mass along a ray from the moon's center to the observer's eye is given to one decimal; thus 5.3 means an air mass 5.3 times the mass along the zenithal ray of an observer at 45° and sea-level. These air masses were found by three-place computing of the moon's geocentric altitude, corrected for parallax and refraction to about 0.1°; values were then taken from Wolff's table.[1] For a station considerably above sea-level, the tabular number for the refracted zenith distance is multiplied by the ratio of the pressure there to 760 mm., pressures being taken from Humphreys' table.[2]

The code used for brevity in this column may be thus illustrated:

c=1.4, relative air mass at mid-eclipse=1.4.

a=2.3, relative air mass at first external contact=2.3.

b 1.7 c, relative air mass at a moment between first external contact and mid-eclipse=1.7.

The grade of the eclipse, 2, 1, or 0, is derived from a comparison of the observations. The tendency in grading has been to favor brightness, *i. e.*, positive statements of visible details have been preferred in general to statements of the contrary. So that the means of brightness grades are not likely to be too low.

It was expected that the arrangement according to air mass would tend to explain some of the discrepancies among the different reports.

[1] H. Wolff, Beiträge zur Geophysik, 11, table, pp. 412-413, 1912.

[2] W. J. Humphreys, Physics of the Air, 1920, p. 72.

But it helps very little. Some of these discrepancies are extremely puzzling.

Take, for example, the total eclipse 1902 X 16.

Barnard, Yerkes Observatory, air mass c=1.1, reports the darkest eclipse in his experience; no surface details visible to the naked eye, few with a 6-inch telescope, and those dimly. This report, by itself, would justify a grade of brightness=0.

Payne, Northfield, Minn., air mass c=1.2, 5-inch telescope, could easily see all the prominent details of the surface, and recognized many of the lesser ones. This by itself would justify brightness=1.

O'Halloran, San Francisco, air mass c=1.3, says that the seas and the white streaks so conspicuous at full moon were visible even without magnifying power.

Godden, London, England, air mass a 4.6 b, could see the seas black as soot, both before and after totality began, with a field glass.

The last two were experienced amateurs; their reports agree well enough, and by themselves would justify brightness=2.

Taking these four definite reports together, the only possible courses are, a compromise grade=1 (the course adopted) or to reject the reports of the amateurs in favor of Barnard's or Payne's. To do this latter, however, is practically to disqualify amateur evidence, which, in the case of many an eclipse, is all the evidence.

Again, the total eclipse of 1895 IX 3;

Barnard and Perrine, Mt. Hamilton, air mass c=1.5, the main features visible to the naked eye, and easily seen in telescopes of 2.5-inch and 12-inch aperture; hence grade=2.

Payne and Wilson, Northfield, Minn., air mass b=1.7, at first no markings visible, soon after, many markings in 16-inch, but invisible in 5-inch finder; grade=0.

Campos-Roderigues, Lisbon-Tapada, air mass b=5, with 11.7 cm. aperture was able to see details, maria and craters, continuously. He says that Aristarchus was notable; but L. Swift, Echo Mountain, Cal., says that Aristarchus was a very inconspicuous object. Grade=1.

The amateurs reporting are also in disagreement, as well as the above professionals. The majority of the observers has been allowed to make the grade=2.

It will be noted that the discrepancies between Mt. Hamilton and Northfield in the two eclipses are not due to different air masses, these being about the same, and are opposite in sign in the two cases.

These two instances are not alone; discrepancies occur of a very puzzling character, and can sometimes be resolved only somewhat arbitrarily. However, in other cases there is unanimity; the eclipse 1903 IV 11 is one—the most certainly dark eclipse in the period studied.

TABLE 1.—*Observations on the Brightness of 68 Lunar Eclipses*

Phase and air mass	*1860 II 6;* 0.812; Grade 2?
c	Pacific, Antarctic ice, Indian Ocean.
	Ward, Dublin, (3); occasional light clouds with halos.
a 1.4 c	N. e. and telescope, size not stated; the seas; Grimaldus shows well; not a trace . . . . of Aristarchus or Plato. . . . . nothing so like as a red hot penny with a little white hot piece at its lower edge.
	Pogson, Hartwell, Engl., (1); sky not stated.
c = 1.4	"With the equatorial," size not stated; actual shadow . . . . indefinite; . . . . visibility—it might almost be termed the brilliancy—of Aristarchus. Kepler and other spots were comparatively lost, or at most barely discernible . . . . in the shadow.
	Schmidt, Athens, (2); very clear sky; occasional light cirrus.
c = 1.8	Means not stated. All parts of the earth's shadow remained without exception completely transparent. (Other details briefly given agree well with Ward.)
	Grade 2, with interrogation point because Ward does not make it absolutely clear that the seas were observed with the naked eye.

	1862 XII 15; 1.415; Grade 0?
c	Portugal, S. Sweden, N. Russia, Siberia, Manchuria, Japan Sea, New Zealand, near Tierra del Fuego, Canary Islands.
a = 5.4	*Cantzler,* Greifswald, Ger., (4); civil twilight most of the time; sky clear, with stars. Means not stated.
a 17.8 b	Eclipsed part invisible.
	d'Arrest, Copenhagen, (5); Means not stated.
———	The moon vanished completely, but its altitude was low and it was seen through heavy haze.
	Grade 0, with interrogation point because of twilight.

	1863 VI 1; 1.224; Grade 0?
c	Bay of Bengal, Asia, Russia, N. Atlantic, Carribean Sea., Antarctic ice, near C. Leeuwin.
	Backhouse, Sunderland, Engl., (6); Clear break in clouds; weak astronomical twilight.
b 4.9 c	N. e. and opera-glass; the greater part of the moon's surface invisible; reflecting telescope, size not stated, Mare Crisium and some other markings, but not the whole surface. Darker than any other that I have seen.
	Bird, (7), place, sky and means not stated.
———	Saw seas and spots, varying with the stage of eclipse; Aristarchus disappeared in the shadow, except at beginning and end.
	Noble, Maresfield, Engl., (8); sky and means not stated.

——— Could see lunar detail at mid-eclipse save just in center of shadow, where everything was obscured.

Tempel, Marseille, (9) ; small stars and even nebulae visible near the moon.

——— Means not stated; could see various-colored spots, and the mountainous regions clearly.

Grade 0, with interrogation point because Backhouse does not state the aperture of his telescope.

1865 IV 11; 0.196; Grade 1

c S. Pacific, Antarctica.

6.9 *Hoefer,* Beauceron, France, (11) ; sky and means not stated, moon about 8° high. The eclipsed part was completely obscured, with no trace of red.

Freeman, Menton, (10) ; clear and serene; the divisions of Saturn's rings and the dusky ring, also 3 satellites, distinctly visible. Bright twilight at mid-eclipse.

c = 17.8 4½ inch; able throughout to distinguish through the shadow the edge of the obscured part of the moon, but could distinguish nothing upon that part.

1865 X 4; 0.344; Grade 1

c Arctic O., Hudson's Bay, E. N. America.

De la Rue, Cranford, Engl., (14) ; night bright, atmosphere tolerably steady.

c = 1.5 4⅛ inch and 13 inch reflector; details plainly perceptible in the telescope, obscured portion perfectly visible without.

——— *Cantzler,* Greifswald, Ger., (12) ; sky not stated, means not definitely stated; the eclipsed limb remained continuously visible.

——— *Flammarion,* (13) ; place, sky and means not stated; the rays of Tycho remained perfectly visible in the middle of the eclipse, as well as the eclipsed amphitheatres and craters.

1867 IX 13; 0.704; Grade 1

c S. Pacific, Antarctica, Indian O.

Ingall, London, (17) ; sky not stated.

c = 1.8 4½ inch; Aristarchus continued to be well seen till nearly the greatest phase, just before which I saw it as an 8th magnitude star, but after that I did not see it at all.

Browning, London, (16) ; sky remarkable for its clearness.

c = 1.8 4 inch, and 10½ inch reflector; the whole surface of the moon was at all times to be made out, many of the markings within the shadow being easily visible . . . . some of the ray streaks.

Slack, London, (18) ; sky not stated, but compare Browning.

c = 1.8 6½ inch reflector; at times the visibility of obscured parts was very striking, [especially at mid-eclipse].

Brothers, Manchester, Engl., (15) ; sky not stated.

c = 1.9 5 inch; during the whole period of the eclipse some of the brighter points of light within the shadow continued visible, as did also the entire disk, with many of the details of light and shade.

1869 I 27; 0.450; Grade 1

c S. W. Pacific, Antarctic ice, S. Indian O.

Prowde, N. Allerton, Engl., (20); sky not stated.

c = 1.3 2⅝ inch; the shadow was of a blackish-brown color, not so ruddy as . . . . sometimes. The main details of the lunar surface were well visible in the telescope through the shadow, and the bright craters were well marked.

Gribble, Constantinople, (19); sky not stated.

c = 1.5 2⅞ inch and 4¼ inch; all the prominent features of the moon's surface under the shadow were quite distinct through [both telescopes] . . . . strong red hue on the eclipsed limb.

1869 VII 22; 0.559; Grade 1

c N. W. Pacific, Bering's Sea, Siberia, Indus Valley, Indian Ocean.

Tebbutt, Windsor, N. S. W., (21); sky not stated.

c = 1.0 3¼ inch; . . . . irregular and ill-defined character of the shadow. The colour of the shadow was very dark iron grey; the red tint . . . . was not noticed. Even with a power of 30 and the illuminated disk [out of] the field, the details of the obscured part of the surface were perceived only with the greatest difficulty. The eclipsed limb . . . . pretty distinct . . . . .

1870 I 17; 1.664; Grade 1

c Antarctica, W. Indian O., Arabia, C. Europe, Greenland, S. California, Pacific.

Tebbutt, Windsor, N. S. W., (22); remarkably well seen . . . . thin filmy cloud till about 11 h. 43 m.

c = 1.8 3¼ inch; . . . . when the moon shone unclouded, the details of the lunar surface began to be perceptible in the telescope. These became gradually more distinct . . . . disk . . . . copper hue throughout the total phase, and continued distinctly visible both to the naked eye and in the telescope.

1870 VII 12; 1.687; Grade 1

c S. Pacific, W. Australia, Indo-China, N. Sweden, Windward Islands, Peru.

Walker, Teignmouth, Engl., (25); sky not stated, astronomical twilight.

d 4.6 e Binocular and sweeper, not clear which used for the following: At 11 h. 47 m. the configurations on the moon's surface were mostly discernible . . . . .

Noble, Maresfield, Engl., (23); clouds till after end of totality.

d = 5.5 4.2 inch; the shadow . . . . browner than I remember to have seen it before. The lunar detail was strikingly visible through it.

Thompson, Cardiff, Wales, (24); sky apparently mostly clear, but clouds a while during totality; twilight, strong toward beginning of observations.

b = 6.6 3½ inch; the seas were distinguishable before and after totality; at totality, the extreme western limb was scarcely visible.

1871 I 6; 0.693; Grade 1

c W. Pacific, Bering's Sea, Arctic N. America.
Birmingham, Millbrook, Ireland, (26); the sky was good enough for him to observe 6 occultations.
c = 1.5 6 foot [= 4½ inch aperture?] The bright parts of the moon had a coppery color, and the dark regions showed a slate blue.

1873 V 11; 1.437; Grade 1

c Missouri and Mackenzie Valleys, Siberia, Siam, Indian Ocean, Antarctic ice, N. Patagonia, far Eastern Pacific, Yucatan.
Tebbutt, Windsor, N. S. W., (27); sky clear.
c = 1.3 4½ inch; at no time during the partial eclipse did the limb or the lunar details become indistinguishable in the telescope, and during the whole of the total phase the moon was plainly visible to the naked eye.

1876 IX 3; 0.341; Grade 1?

c Antarctica, Australia.
Perrotin, Toulouse, (30); interrupted by clouds; means not stated.
c = 2.2 The eclipsed limb was clearly seen, and also the lunar surface, particularly the part near the shadow boundary.
Arcimis, Cadiz, Spain, (28); atmosphere magnificent, not a cloud . . . . extraordinary and exceptional purity.
a 3.1 c 4 inch and d. v. spectroscope; [The inner shadow was too dark to give a spectrum, which was obtainable only near the boundary].
F. R. A. S., (29); place, etc., not stated.
——— I remember myself how very nearly the moon disappeared from the sky on October 4, 1884, and also the notable darkness of the earth's shadow during the partial eclipse of Sept. 3, 1876.

Grade 1, with interrogation point because of indefinite data.

1877 II 27; 1.671; Grade 2

c Antarctica, Pacific, E. Siberia, Greenland, near C. Verde.
v. Sterneck, Vienna, (35); sky not stated.
c = 2.2 6.4 cm. and 9.5 cm.; certain parts of the moon's surface, as Mare Serenitatis, Imbrium, and several others, appeared of a brighter red than their surroundings and stood out clearly from them. Aristarchus too was clearly visible as a shining point after its immersion till 7 h., and for an equal time before its emersion.
Barber, Rome, Italy, (33); the sky was so good that 8 very small stars were visible to him within one diameter distance from the moon, and the Galaxy and Zodiacal Light were brilliant.
c = 2.3 1¼ inch; at the middle of the eclipse the central parts of the lunar disk were especially dark, and the markings upon it were barely to be distinguished; the circumference . . . . was much brighter.
Riccò, Modena, (34); sky not stated.

c=2.5 The red light of the umbra was so intense, that during totality it produced distinct shadows of the telescopes and other objects illuminated by it.

Arcimis, Cadiz, Spain, (32); clear after beginning of totality; weak astronomical twilight.

c 4.3. d N. e. and telescope, aperture not stated; no details were distinguishable by either.

A. H. S., (31); place and sky not stated.

——— 6½ inch reflector, after beginning of totality; what struck me most was the absence of bright spots, such as Aristarchus.

1877 VIII 23; 1.761; Grade 2

c Antarctica, E. Indian O., Malay Pen., Nova Zemlya, Greenland, Labrador, Carribean Sea, E. S. Pacific.

Johnson, Crediton, Engl., (37); not a cloud throughout.

c 1.4 d 2¼ inch; Mare Crisium, Fecunditatis, Nectaris, Tranquilitatis, Serenitatis in a smoky gloom. . . . .

Rand Capron, Guildford, Engl., (39); sky not stated.

d=2.2 8½ inch; as shadow began to pass off . . . . the indistinctness noticeable during approach and continuance of totality gave way to a considerable sharpness of the moon's features as seen through the shadow. The shadowed part glowed with a richer copper tint, on which were seen dark, almost black, spots and patches. . . . . A good field glass rendered them hardly less distinct.

3¼ inch; the dark spots or patches were distinguished to be moon details, but they were remarkably sharp and well-defined. [He says the same of details with 3¼ inch before totality.]

Maunder, Greenwich, (38); sky not stated.

c=2.3 . . . . to the n. e. the eclipsed part was fairly bright and of a coppery hue, and the details of the surface seen with great distinctness. . . . .

Elger, Bedford, Engl., (36); exceptionally favorable circumstances.

a 2.7 b . . . . details visible in the finder [of the 4 inch].

1878 VIII 12; 0.590; Grade 0

c White Sea, Greenland, Labrador, Florida.

Maunder, Greenwich, (41); sky not stated.

c=2.5 Finder of the great equatorial; . . . . the eclipsed part completely cut out, the shadow being so dense and black that the outline of the moon's limb could not be traced under it, even in imagination; nor could any features be made out on the eclipsed part, except at the very edge of the shadow.

Slack, Forest Row, Engl., (42); occasional cirro-stratus.

c=2.5 6¼ inch reflector; Copernicus faintly visible as a pale white spot . . . . most of the umbra coppery, but not bright or transparent. All through the eclipse the umbra was darkest at the approaching margin for a width about equal to that of Copernicus. . . . . Moon's limb always visible, if faintly.

E. E. M., (40); place and sky not stated; probably somewhere in England.

——— 2¾ inch. I could detect the limb of the moon through the shadow almost as soon as it began to creep over the disk. . . . . At 11 o'clock the moon presented a superb spectacle, blood-red. . . . .

1880 VI 21; 1.071; Grade 2?

c S. W. Pacific, Antarctic ice, Antarctic and Indian oceans.

Tebbutt, Windsor, N. S. W., (45); cloudless.

c = 1.0 4½ inch; . . . . badly defined nature of the periphery of the shadow . . . . the eclipsed moon a conspicuous object . . . . unusual brightness for a total eclipse, especially on the southern limb.

c = 1.0 (43); nothing about means or sky; well seen at *Melbourne Observatory* . . . . the usual copper-red colour . . . . the western edge of the moon retained a greater brightness than the rest of its surface during the whole period of totality. . . . . The features of the moon were plainly visible throughout the darkest phases.

Russell, Sydney, N. S. W., (44); air very clear and nearly calm.

c = 1.0 11½ inch; . . . . the red light . . . . more conspicuous, and yet was so translucent that all the conspicuous features of the moon could be seen, even the markings on the inner wall of the Aristarchus, etc.

Grade 2, with interrogation point because dependent so largely on Tebbutt's recollection of previous eclipses.

1881 VI 11; 1.365; Grade 1

c N. Atlantic, Artic N. America, N. Pacific; almost a complete great circle of sea.

Barnard, Nashville, Tenn., (46); sky not stated.

c = 2.1 . . . . the moon was strikingly conspicuous during totality. It was of a beautiful bright cherry red, and the general details of its surface were very noticeable in a 5 inch telescope.

Hall, Washington, D. C., (47); means and sky not stated.

c = 2.6 Nearly all the details of the surface of the moon could be seen during the total eclipse.

Hooper, Harvard, Mass., (48); clear; faint astronomical twilight.

c = 3.3 4 inch; . . . . even during the middle of totality . . . . the most prominent details of lunar scenery were easily made out. Color . . . . a dull orange red.

1881 XII 4; 0.979; Grade 2

c S. Pacific, Antarctic ice, S. Africa.

Piat, Bagdad, (51); very cold; nothing but sky.

c = 1.2 Good opera-glass; in the red region the details were perfectly distinguishable.

Johnson, Bridport, Engl., (50); sky propitious, civil twilight.

c = 6.9 Telescope, aperture not stated; western seas; Aristarchus, a white spot in the coppery disk . . . . continued so.

Rand Capron, (52); place not stated; the moon was low and the night misty; small banks of clouds on the horizon; in England somewhere. 3¼ inch; no red patches or brilliant tints were seen, but the moon's configuration was well made out through the shadow.

1884 IV 9; 1.438; Grade 0?

c Antarctica, Indian O., Burmah, Lena Valley, Mississippi Valley, Yucatan.

c=4.9 Java, Java Head, astronomical twilight.

c=2.8 Java, Bantiman, dark.

Ch. Dufour, (53), states, on an authority not given, that the very rare occurrence of a dark eclipse, in which the moon disappears, happened twice in the year 1884, as it was observed, first, Apr. 10, in the island of Java, second, October 4, in Europe. Java Head and Bantiman are extreme maritime positions given in Bowditch's Navigator.

Grade 0, with interrogation point because the original authority is not stated definitely.

1884 X 4; 1.533; Grade 1

c Lena Valley, Arctic Archipelago, New England, Venezuela, E. Argentina, Antarctica, far Western Australia, China Sea.

This eclipse was widely observed in Europe, and has generally been classed with dark eclipses like that of 1816. But the records hardly justify that; while Young's General Astronomy, (1898), p. 254, says, ". . . . the moon was absolutely invisible to the naked eye . . . .," the following observations show that it was brighter, though quite dim. Coming in the period of the Krakatoa phenomena, it was much discussed in that connection.

Parséhian, Constantinople, (63); conditions excellent.

c=1.2 5.0 cm.; Tycho, like a star of the second magnitude. The moon during totality was feebly but definitely colored in red.

Berge, Romorantin, France, (55); nothing about sky or means.

c=1.5 During totality the eclipsed moon remained constantly visible, and the Mare Tranquilitatis, Mare Serenitatis, Oceanus Procellarum, etc., were easily distinguished.

Byl, Brussels, (56); atmospheric conditions hardly favorable, sky very cloudy and often completely covered.

c=1.6 10 cm.; during totality the disk was continuously visible, colored dark red, with a luminous circle around, white within, blue without. The seas were visible as brownish spots, very dark; the peaks, as brilliant points with slight red aureoles.

Guiot, Soissons, France, (60); nothing about sky or means.

b 1.6 c Moon very dark, although sharp; Tycho, Copernicus, Plato and Grimaldi easily seen, but not Aristarchus.

Trépied, Paris Obsy., (65); sky not stated.

b 1.6 c 25 cm.; early in the partial stage the shadow edge was tinted red, and beyond 2′ or 3′ within it nothing was perceptible. Later the shadow suddenly brightened, it became possible to see the limb and the principal details of the surface. On the whole the shadow was completely uniform, of a pale but decided blue.

Spitta, Clapham, Engl., (64); sky cloudless.

c=1.6 10 inch reflector; during totality the moon was, generally speaking, exceedingly faint . . . . at times barely visible to the n. e., and presented none of the coppery color usual on these occasions. It was bluish at the lower edge. . . . . No markings were plain enough to be recognized.

Beechey, Downham, Engl., (54); sky and means not stated.

c = 1.7 During totality it presented one equal flat tint of cold grey, through which every feature of the lunar surface was distinctly visible.

Denning, Bristol, Engl., (57); perfectly cloudless sky.

c = 1.7 10 inch reflector; . . . . her sharply circular contour, however, still admitted of satisfactory observation, and many leading features of the surface were recognized amid the prevailing gloom; . . . . interior region the coloring . . . . dark reddish brown.

Guillaume, Perronas, France, (59); nothing about means or sky; the
b 1.7 c seas were all visible.

Lowe, Chepstowe, Engl., (61); sky cloudless, stars very brilliant.

c = 1.7 Telescope, aperture not stated. Having previously observed a number of lunar eclipses, ... the density and blackness of the shadow was far greater than any previous one that I had seen. In all previous eclipses I have been able to trace the outline; in the present case this was quite impossible. The moon had more the appearance of a large star whose light was just able to pierce through a dense haze. [He nowhere in his long account says anything of surface details.]

Muller, Copenhagen, (62), and wife. Nothing about sky or means.

b = 1.8 Immediately after the beginning of totality, saw a bright red copper disk, which lasted perhaps 2 m. Others in Copenhagen agreed as to the color, but not as to intensity; outside of Copenhagen Danish observers noted fainter reds.

Erck, Shankill, Ireland, (58); most favorable circumstances.

c = 1.8 Means not stated. Obscuration so great that the disk could hardly be discerned with the n. e. There were changes in the brightness of the surface, described with sketches.

In his summary, Flammarion says that there are brought out curious and striking discrepancies among the accounts received. This is clear in the above. Such discrepancies seem frequent in descriptions of dim eclipses, of which this was surely one.

1885 III 30; 0.886; Grade 1

c N. Pacific, Bering's Sea, Finland.

Buisson, St. Denis, Réunion, (69); temps splendide; astronomical twilight at beginning.

a 4.3 c 10.8 cm.; the eclipsed limb became invisible at 6 h. 57 m., l. m. t., and
c 1.4 e remained so till near last contact; about 9 h. 15 m., l. m. t., Aristarchus and Mare Crisium were sometimes visible; during a great part of the eclipse the shadowed part was entirely or nearly invisible. Colors not mentioned.

Biggs, Launceston, Tasmania, (67); quotation from Launceston "Examiner"; sky and size of telescope not stated, but he observed constantly for three hours.

c = 1.5 [At most (mid-eclipse) 25° of the eclipsed limb was visible, from the shadow-border inward; with this exception] all within the shadow was utterly obliterated—lost in the dead slaty tint of the sky. I could not distinguish a single crater after once it was fairly within the shadow. Not the slightest trace of the coppery tint was visible throughout.

Ballot, Rolfontein, Transvaal, (66); detached clouds; astronomical twilight.

a 4.0 c 6 inch; when the shadow line had reached to midway between Plato and Aristarchus, I could plainly trace the limbs of the obscured part all round.

Broune, Odessa, (68); sky pure to the end; bright civil twilight at beginning of observations = mid-eclipse.

c = 18.2 12 cm.; Kepler and Aristarchus shone brilliantly as usual. The eclipsed part was colored blue like the surrounding sky. The eclipsed limb was invisible in telescope and in opera-glass, even quite close to the bright part.

1887 VIII 3; 0.424; Grade 0?

c Siberia, Kara Sea, N. Atlantic.

Rayet, Bordeaux, (73); sky very fine; astronomical twilight at mid-eclipse.

c = 4.4 38 cm.; the whole disk of the moon never ceased to be visible in the telescope, and the eclipsed part showed no coloration at all sensible.

Klein, Cologne, (71); clear sky; astronomical twilight.

c = 4.7 3 foot [= 2¼ inch?] and 6 foot [= 4½ inch?] No details visible in the eclipsed part, except toward the end.

Grade 0, with interrogation point because all observations were made in weak twilight; this weakens the evidence for a dark eclipse, though it would strengthen that for a bright eclipse.

1888 I 28; 1.647; Grade 2

c Antarctic ice, S. W. Atlantic, Pampas, Ecuador, Mississippi Valley, near Pt. Barrow, E. Asia, Cochin China, S. W. Indian O.

Brugière, Marseille, (74); sky not stated.

b = 1.2 Opera-glass; of the lunar surface in the shadow, the seas are dark and the plains are bright, easily visible.

Terby, Brussels, (78); lunar corona in light clouds at beginning, and a halo at end.

c = 1.2 Equatorial and n. e.; remarkable for the intensity of the red coloration, which caused the surface details to be constantly perceived.

L. N(iesten?), Brussels Obsy., (76); advantageous conditions.

c = 1.2 During totality, for 1 h. 38 m., it was not absolutely obscured, but as if covered with a red veil, through which the eye could follow the contours of the principal spots.

——— *Soc. Astr. France,* (77); several members report corroborating the above.

Fromme, Giessen, (75); sky continuously clear.

c = 1.2 The seas easily visible to the n. e. throughout totality.

1888 VII 22; 1.816; Grade 1

c — S. Greenland, Arctic Archipelago, near Sitka, Pacific, Wilke's Land, Cape Colony, Gulf of Guinea, Morocco, N. Atlantic.

Barnard, Mt. Hamilton, (79); evening clear.

c = 2.3 — 6½ inch; details during totality singularly indistinct.

Valderrama, Teneriffe, (82); sky not stated; dawn at mid-eclipse, *i. e.,* strong astronomical twilight.

b = 2.3
c = 7.7 — 2½ inch and opera-glass; during totality the configurations of the lunar surface were continuously visible.

Duprat, Constantine, Algeria, (80); sky very pure; dawn a hindrance to color observations; means not stated, but his figure must have been

a = 8.5 — made with a telescope. The eclipsed part was absolutely invisible.

——— *G. H.,* New Orleans, (81); and *Romani,* Port-au-Prince, (81a), both had very favorable conditions, but otherwise report very incompletely. Both speak of the copper color and redness of the moon.

1889 I 16; 0.696; Grade 0

c — Libya, Black Sea, Russia, Siberia.

Barnard, Mt. Hamilton, (83); sky not stated, but he observed throughout the eclipse.

c = 1.1 — 12 inch; the obscured portion of the disk was conspicuous to the n. e. throughout nearly all the eclipse, and appeared of a lightish red color . . . . . The prominent objects were easily seen within the shadow [presumably with the telescope].

Mitchell, Chester, Engl., (86); beautifully clear, clouded over before mid-eclipse.

c = 2.5 — 8½ inch reflector; with a low power the darkened limb was just visible.

Eginitis and *Maturana,* Paris, (85); sky fine at first, completely covered after mid-eclipse.

c = 2.9 — Équatorial ouest; the different craters, and in general all the details of the eclipsed part very clearly distinguished.

Stuyvaert, Brussels, (87); favorable weather, image throughout sharp and steady.

c = 3.0 — 15 cm.; the lunar formations disappeared rapidly as soon as they were invaded by the shadow.

le Cadet, Lyons, (84); sky not stated.

c = 3.2 — 38 cm.; almost all the details visible in the shadow.

1889 VII 12; 0.486; Grade 0

c — N. S. Wales, Antarctic ice, Magellan Str.

Riccò, Palermo, (93); sky apparently clear.

c = 2.9 — 25 cm.; notable lack of light and color compared with preceding eclipses. Aristarchus visible a while after immersion.

Mascari, with Riccò.

c = 2.9 — 25 cm.; shadow very dark, Aristarchus hardly visible, in contrast with other eclipses, when it and others were very visible.

v. Gothard, Hérény, (88); sky not stated; astronomical twilight.

c = 4.2 4½ inch; the eclipsed part was very dark, grayish black.

v. Konkoly, O'Gyalla, (89); sky not stated, but a halo stopped observations later; astronomical twilight.

c = 4.2 6 inch; at mid-eclipse could see the eclipsed part only with the bright segment out of the field.

Krueger, Kiel, (90); sky and means not stated.

——— The brilliancy of Aristarchus in the surrounding gloom was very striking.

1891 V 23; 1.306; Grade 1

c N. W. Pacific, Saghalien, N. Russia, Italy, Sahara, near C. Palmas, Graham Land, S. Pacific.

Wooster, Ballarat East, Victoria, (96); beautifully clear.

c = 1.7 8 inch reflector; some of the larger and bolder formations were traceable during the whole of totality. After passing the center of the shadow, though still wholly immersed in it, the N. and E. parts became much lighter, quite a pale ash color, in which Sinus Iridum, Plato, Aristarchus, Grimaldi, etc., stood out boldly.

Jackson, Constantinople, (94); moon rose out of haze and fog; apparently clear thereafter; weak astronomical twilight about end of totality.

d = 3.7 6 inch; [½ hr. before end of totality] Aristarchus and the region immediately north of it became conspicuous, and increased in brightness from that time forwards. The moon was visible to the n. e. throughout.

Lewitsky, Kharkov, (95); cloudless sky, astronomical twilight.

c 5.1 d 3 inch; the whole disk plainly visible, with some formations visible but dim.

1891 XI 15; 1.393; Grade 2

c Antarctic ice, Indian O., B. of Bengal, near Yakutsk, Alaska, Rocky Mountains, near Manzanillo, S. Pacific.

Gore, Ballysodare, Ireland, (98); clear and cloudless sky.

d 1.3 e Binocular; markings on dark part pretty conspicuous.

Power, Cape Observatory, (100); clear.

b = 1.8 N. e., [from context;] the coppery hue characteristic of "bright" eclipses was distinctly visible . . . . there were darker patches on the coppery surface . . . . it resembled drawings of Mars, with patches of darker shade scattered over the moon's surface.

——— *Fenet,* Beauvais, France, (97), and *Decroupet,* Soumagne, both with good sky, used opera-glasses, and report seeing the spots and configurations. Others with larger telescopes agree as to the brightness

——— and visibility of details. But *Leslie,* Southampton, Engl., (99), clear sky, "glasses," says that "the darkness and absence of color of the shaded part of the moon was even more marked in this eclipse than in that of October 4, 1884."

1892 V 11; 0.953; Grade 2

c Antarctic ice, S. E. Pacific.

Codde and others, Marseille, (101); good conditions.

c = 2.2 16 cm.; Kepler . . . . and the principal topographic details are very visible.

Goodacre, Highgate, Engl., (103); weather clear; markings more
c = 3.3 distinct to the n. e. than in the telescope.

Crossley and Gledhill, Halifax, Engl., (102); weather all that could be desired.
c = 3.7 The principal lunar seas, etc., were readily seen and identified with the help of an opera-glass.

Observers at Louvain, (104), saw the seas and the northern region of
——— the moon with the n. e. Others, at various points, with telescopes large and small, report visibility of details.

1892 XI 4; 1.092; Grade 0

c C. Europe, N. Sea, N. Atlantic, Greenland, Baffin's Bay, Queen Charlotte's Sd., S. Pacific, Antarctica, Mozambique Channel, Tripoli.

Gale, Paddington, Sydney, N. S. W., (107); well seen, in spite of haze and light cloud.
c = 2.0 8½ inch reflector; the want of sharpness of objects on the lunar surface was noticeable throughout, although Jupiter was very well defined with power 280. . . . . Detail was only seen near the northern and western limbs during the total phase.

Russell, Sydney Obsy., (110); was occupied with photographs of the
——— eclipse, and makes no report about the visibility of details, except that none were visible for a while after first contact; aperture not stated, breaks in clouds. The coppery color was brilliant, except in early stages. Contrary to the prediction of the Nautical Almanac, he says that this eclipse as observed was certainly not total.

Doberck, Hong Kong Obsy., (106); weather not stated; 2¼ inch
——— binocular; nothing about visibility of details; the early shadow was bluish gray, the later stages brighter.

In France, the moon rose in bright twilight, past totality. *Gio-*
——— *vanozzi,* Florence, (108), and *Cortel,* Chateau Chinon, (105), both say that the eclipsed part was entirely invisible, not distinguishable from
——— the sky. *v. Glasenapp,* Abastuman, (109), emphasizes the varying intensity of the red color, and gives the moment of its disappearance, 5 h. 04 m. G. M. T., which agrees with Russell's statement of 5 h. 03 m. He says nothing of details.

1894 III 21; 0.248; Grade 0

c N. W. Pacific, Mackenzie Valley, Arctic O., E. of Ural Mts.

Rzyszczewski, Minoussinsk, E. Siberia, (111); sky completely pure; twilight over mid-eclipse.
c = 3.0 7.2 cm.; he notes (1), the complete invisibility, even in the field of my telescope, ... of the eclipsed part of the moon . . . . for even the contour of the disk was invisible. (2) . . . . the shadow was like an opaque smoke, completely black, with a slight greenish shimmer. (3) The eclipsed part is much more invisible, both to the n. e. and in the telescope, than the ashy disk of our satellite during the first days of the first quarter. . . . .

1894 IX 14; 0.231; Grade 2

c Antarctica, S. and C. Africa.

Barnard, Mt. Hamilton, (112); sky not stated, but he observed and made photographs all through.

c = 2.0 12 inch and its finder; in 12 inch, a pale, ashy, dusty shade, with scarcely any boundary line; in finder, outline of shadow quite marked. Limb of the moon and details on the surface seen while in shadow—limb more conspicuous than at same stage in other eclipses. . . . . I think it was lighter than usual.

Comas-Sola, Barcelona, (113); excellent sky; astronomical twilight.

c = 5.2 Opera-glass; there are seen in the shadowed part the principal lunar configurations, as Mare Imbrium, Mare Frigoris, etc. . . . . In spite of dawn and low altitude, the eclipsed part more visible than ever [at about a quarter-hour before end of totality. He observed *no red.*]

Riccò and *Mascari,* Catania, (116), *Pilloy,* Chateau-Thierry, (115), *Ladoux,* Frontignan, (114), agree as to the lead color of the shadow, Pilloy seeing a faint tint of red.

1895 III 10; 1.627; Grade 2

c E. Black Sea, near Nova Zemlya, Alaska, Pacific, Antarctica, Portuguese E. Africa, middle Red Sea.

Observers at Northfield, Minn., (124); sky beautifully clear.

c = 1.7 At the edge of the umbra the light was quite bright, so that the more prominent details of the moon's surface could be seen with the n. e. . . . . Toward the center of the shadow the illumination lessened rapidly . . . . the surface markings could hardly be distinguished [with the n. e.?].

Duménil, Yébleron, France, (119); aureole and halo.

c = 2.3 Marine glass, 5.8 cm.; in the early stages, shadow black like soot, no detail visible. Previous to mid-eclipse, brighter, few details visible, but Mare Crisium pretty plain. Later during totality, the moon was absolutely invisible to the n. e.

Martial, Ploërmel, France, (122); sky of perfect limpidity.

c = 2.3 5.7 cm.; much like the report of Duménil, except that he was not able ever to see any details during totality.

Everett, Greenwich, Engl., (121); nothing about sky.

c = 2.4 Opera-glass; ruddiness confined to lower half of disk; 4 inch; no ruddiness, maria easily seen in telescope.

Bosshard, Winterthur, Switz., (117); clear, except for occasional small thin clouds near the end.

c = 2.6 3½ inch; at beginning of totality, Mare Crisium weakly visible; this and other details were not noted at mid-eclipse; Grimaldi appeared as a dark spot just before end of totality.

c = 2.9 *Perrine,* Mt. Hamilton, (125); haze the entire evening, sufficiently thick to interfere materially, especially with the occultations. The moon's disk was visible at all times, and quite conspicuous except for a brief time at mid-transit, and even then the outlines of the principal dark areas were visible to the n. e.

Eddie, Grahamstown, Cape Colony, (120); sky apparently good; twilight came with beginning of totality.

b = 3.7 Aperture not stated. All lunar detail was completely obliterated, and though it was decidedly a red eclipse, it was undoubtedly a very dark one.

——— *Comstock,* Madison, Wis., (118); perfectly clear sky; noteworthy for the unusual brightness of the moon during totality.

——— *Quélin,* Angers, France, (126); at first a halo, then clear. Aperture not stated; no detail visible in telescope, and, part of the time, moon invisible.

——— *Rudaux,* Donville, France, (127); sky and means not stated, but he observed throughout totality, and no doubt with telescope.

Comparing his sketches of the eclipse with theory, he concludes that the apparent center of the shadow is north of the theoretical center. Whence one may conclude, he says, that the terrestrial southern hemisphere enjoys an atmosphere very pure, refracting the solar light *en entier.* [Sketches not published by editor.]

Newbegin, (123); place not stated, no doubt in England; fine and clear, [last hour of totality].

——— Finder, aperture not stated; the whole outline of the moon and all the details of the surface were most distinct. . . . .

1895 IX 3; 1.557; Grade 2

c Antarctica, S. Atlantic, Ashanti, Morocco, Iceland, near Bering's Str., New Zealand.

Nauwelaerts, Rosario de Santa Fe, Arg., (131); fairly good sky up to totality.

c = 1.3 Aperture not stated; Aristarchus remained visible some time, Kepler, Copernicus and Tycho disappeared almost at the time of contact with the shadow. At totality, to the n. e., the color is reddish. . . . . In the telescope, ... all the selenographic configuration is readily visible. . . . . Certain regions, as the Mare Fecunditatis and Mare Serenitatis, are very dark.

Barnard, Mt. Hamilton, (128); night very satisfactory; observed throughout eclipse.

c = 1.5 2½ inch; in telescope all the lunar details clearly seen. The dark regions seen easily with the n. e.

Perrine, Mt. Hamilton, (133); sky overhead clear, and the air very transparent.

c = 1.5 12 inch. The moon remained plainly visible all through the total phase, the main features being discernible with the n. e., and distinct in the telescope.

Payne and *Wilson,* Northfield, Minn., (132); sky cloudless, hazy at beginning, clear afterwards.

b = 1.7 Shadow at first very dark, to n. e. almost black; . . . . . No details visible till [about 10 m. after second contact] when Aristarchus was dimly seen. Soon after, many markings visible in 16 inch, but invisible in 5 inch finder.

Campos-Roderigues, Lisbon-Tapada, (129); sky not stated; totality began in mid-twilight.

b = 5.0 11.7 cm.; the details of the disk were continuously visible, particularly

c = 17.8 the contours of the maria, and certain craters, notably Aristarchus and Manilius.

Flammarion, Juvisy, France, (130); sky hazy; strong astronomical twilight.

a 7.6 b The half-eclipsed moon hard to see, with n. e. and opera-glass, on the field of the sky.

Roulaud, Dragueville, France, (134); sky and means not stated.

——— The principal spots were visible.

Véréri, Bellevue, France, (136); sky and means not stated.

——— The shadow was entirely black.

Swift, Echo Mt., Cal., (135); cloudless sky.

——— Aristarchus was on this occasion a very inconspicuous object, not noticeable unless looked for.

1896 II 28; 0.870; Grade 2

c Antarctica, S. Atlantic.

Möller, Bothkamp, (138); sky not stated.

c = 2.4 6.0 cm.; the smaller craters were visible after immersion only in the neighborhood of the shadow-edge, and no longer after they had penetrated deeper into the shadow.

W. P (*rinz?*), Uccle, Belgium, (141); sky almost completely hidden.

c = 2.6 To the n. e., the shadow which covered the moon was reddish, and grayer toward the center of the disk; in it one could distinguish the gray spots of the lunar seas as well as the brilliant crater Tycho.

Duménil, [Yébleron], (137); apparently a pretty good sky between clouds.

c = 2.8 Marine glass, 5 cm.; the light rose-color which covered 8/10 of the surface was admirably transparent. In it there were perceived all the details; continents and mountains, very blue; the seas, a little more gray.

Taylor, S. Kensington, Engl., (140).

c = 3.0 2 inch; the principal lunar seas and formations were easily seen through the red part of the shadow, which was redder to the n. e. than in a 2 inch o. g.

Roberts, Aberdeen, Scotland, (139); sky not stated.

c = 3.2 The maria could be distinctly traced with the n. e.

1898 I 7; 0.157; Grade 1

c Siberia, near Bering's Str., Alaska.

Stuyvaert, Brussels, (145); excellent conditions.

c = 1.1 38 cm.; the shadow was throughout of a uniform slate gray. For a while after beginning, and again before ending, the brilliant ray extending S. E. from Tycho was visible in the shadow. Previous to the middle of the eclipse the immersed limb was seen only with difficulty.

Chèvremont, Congis, France, (142); during the eclipse the sky was perfectly limpid.

c = 1.1 6.0 cm.; about mid-eclipse the shadow is so dense that the details of the surface disappear entirely; but, a curious fact, the bright ray extending S. S. E. from Tycho is clearly visible throughout its whole extent . . . . with telescope. These conditions persisted throughout the eclipse.

—— *Guiot,* Soissons, (144); says that to n. e. the limb was entirely invisible.

Godden, [London?], (143); night calm and slightly foggy.

c = 1.1 15/16 inch and 3 inch; could see the limb, but no surface detail whatever.

1898 VII 3; 0.934; Grade 2

c Southern Pacific Ocean, Australia.

Saija, Catania, (153); sky clear throughout eclipse.

a 3.0 c 12 cm.; a little way inside the shadow edge the lunar topography is not visible.

Riccò, Catania, (152); sky clear throughout eclipse.

a 3.0 c 15.3 cm.; Aristarchus brilliant, Kepler and Copernicus well seen.

Marckwick, Gibraltar, (150); very favorable circumstances.

c 3.2 e Binocular; possibly many would hardly have noticed there was an eclipse . . . . . The principal markings of the lunar disk seen perfectly well in the shadow.

Moye, Bordeaux, (151); sky not stated.

[About half-an-hour before mid-eclipse] with an opera-glass there are visible in the shadow the Mare Crisium and the principal lunar configurations. . . . .

c 3.5 e [About a half-hour after mid-eclipse] with an opera-glass the Mare Crisium is visible in the shadow, dark on a brighter ground. Proclus shines with a reddish light in the shadow.

Struve, Kharkov, (154); clear at first, clouds during second half.

c = 3.7 6 inch; the eclipsed part of the moon was pretty dark, but in the 6 inch refractor the largest craters could still be recognized in the shadow; but not in smaller telescopes.

Weinek, Prague, (156); good weather, after a while completely clear.

a 3.8 c 9.76 cm.; he mentions various details as visible at different times, particularly Mare Crisium and Aristarchus.

Ambronn, Göttingen, (146); thin filaments of cirro-stratus.

c 4.3 e 8.3 cm.; the more sharply limited seas and craters are also visible in the eclipsed part.

Grein, St. Emilion, France, (148); sky not stated.

c = 5.2 4.3 cm.; at maximum eclipse he could see the principal spots, a little vaguely; with n. e., nothing.

Gaythorpe, Barrow-in-Furness, Engl., (147); breaks between clouds, later clear and observations continuous.

e = 6.1 3 inch, [during latter half]. When the illuminated portion of the moon was moved out of the field, the umbra was sufficiently transparent to show the Mare Crisium, and a few of the neighboring ring-plains, such as Cleomedes.

Véréri, Bellevue, France, (155); sky not stated; astronomical twilight.

a 6.4 c The red coloration is particularly intense on the eastern part of the limb; it shades off gradually towards the still illuminated region, and permits the seas of Serenity and Tranquillity to be seen by the n. e. and with an opera-glass.

Hauët, Paris, (149); cleared up sufficiently for good observations. Astronomical twilight.

c = 6.4 At maximum eclipse, with n. e., the contours of the eclipsed portion were clearly visible. The principal spots were equally visible through the shadow. . . . .

1898 XII 27; 1.384; Grade 2

c S. Atlantic, near Santiago, near Vera Cruz, near Sitka, near Bering's Str., near Bangkok, Indian O.

Whichello, Chester, Engl., (169); cleared off before first contact.

c = 1.1 During totality, both by n. e. and in 9 inch reflector, outlines of the maria, etc., could be easily seen.

Staus and *Mündler,* Frankenthal, Ger., (167); clear air during totality.

c = 1.1 3 inch; details mentioned as visible in the shadow, Tycho and Aristarchus.

Bareel, Louvain, (157); bad state of sky and strong wind.

a 1.1 b 6 inch; all the seas visible in the equatorial, but not Tycho.

King, Leicester, Engl., (164); clear breaks in clouds.

d 1.2 e 2 inch; details well seen.

Blacklock, Gateshead, Engl., (158); unclouded and nearly black sky.

c = 1.2 3½ inch reflector; during the whole time the details of the moon's surface were distinctly visible in the telescope.

Gaythorpe, Barrow-in-Furness, Engl., (162); sky clear, strong wind.

b 1.2 c 3 inch; . . . . everywhere sufficiently transparent to allow most of the coarser details to be seen.

Smith, Edinburgh, Scotland, (166); observed the eclipse through intervals in the clouds.

c = 1.2 All through, the dusky surface markings were easily seen with the n. e.

Franz, Breslau, Ger., (161); sky not stated.

c = 1.2 3½ inch; easily visible during totality—Grimaldi, Aristarchus, Sinus Iridum, Plato, Promontorium Acherusia, Manilius, Menelaus.

Ellison, Monkswearmouth, Engl., (159); perfectly clear sky all through.

a-b 4 inch; Grimaldi, Mare Crisium, and other dark spots within the umbra very distinct. . . . . Tycho and rays noted to be very conspicuous.

Fauth, Landstuhl, Ger., (160); occasional cirrus.

c 17.8 cm.; spots, and rays of Tycho, Copernicus and Kepler perfectly clear during totality.

Killip, St.-Anne's-on-the-Sea, Engl., (163); clear sky.

c 5 inch; detail everywhere remarkable. Menelaus and Manilius only a little less bright than Aristarchus. The rays from Tycho very fine.

Stuyvaert, Uccle, Belgium, (168); sky clear.

c 15 cm.; the great configurations of the seas are visible; Aristarchus brilliant. . . . . All selenographic details are very visible.

"No Sig," (165); place not named; moon quite clear, and so remained.

c The features on the moon's surface were discernible with the n. e., the contrast between seas and highlands being well marked. 9 inch reflector; Tycho, Grimaldi, many of the streaks, Plato, and so on.

1899 VI 22; 1.487; Grade 0?

c Siberia, near end of Aliaska Pen., Pacific, W. Antarctica, S. Atlantic, near Antanarivo, Indus Valley.

Bernacchi, Cape Adare, Antarctica, (170); fine and clear, but misty; but small stars in Sagitta and Crux were visible during totality. Aperture not stated; he calls it "the big telescope." Eclipse visible throughout.

c = 1.6 During this time there was absolutely no . . . . detail observable on the lunar surface, and at no time was the whole of the disk visible. . . . . During the first half of totality the western limit was of a dull red color, and the eastern quite invisible. During the latter half it was the reverse.

Grade 0, with interrogation point because of the mist, and the aperture not being given.

1899 XII 16; 0.996*; Grade 2

c Far S. Atlantic and Pacific, Weddell Sea.

Lafitte, Saïda, Algeria, (176); sky not stated.

a 0.9 c Opera-glass; the principal seas.

Saija, Catania, (180); sky clear throughout.

a 1.1 c In the finder, 4 cm., the topography of the eclipsed part is entirely invisible, but in the telescope, 15 cm., well enough.

Daguin, Beyris, France, (172); sky very pure, stars brilliant, the red
a 1.1 c color is bright and sufficiently transparent to allow details to be recognized in it, even without telescope.

Grein, St. Hippolyte, France, (174); sky not stated.

c = 1.1 4.3 cm.; the principal spots were quite visible.

King, Leicester, Engl., (175); clear sky throughout.

a 1.2 c 2⅛ inch; the seas plainly visible.

Luzet, Mareilly-en-Villette, France, (178); exceptional conditions.

c = 1.2 4.3 cm.; the general background during maximum eclipse, bright wine-color, the seas a decidedly bluish ashy color.

Crusinberry, Des Moines, Iowa, (171); sky slightly hazy; aperture not
c = 2.0 stated. At the middle of the eclipse the center of the moon was quite dark, but the "seas" showed up finely in the finder of the telescope, and Tycho was quite easily seen.

Gaubert, Martinique, (173); sky admirable; aperture not stated.

—— The cirques, seas, the lunar topography were perfectly visible during maximum.

Levreau, Santiago del Estero, Arg., (177); sky and means not stated.

—— The form of the seas very visible in the shadow.

Maclachlan, Largs, N. B., (179).

—— 5 inch; the details of the features of the moon were curiously irregular in visibility . . . . without any apparent cause, such as interference by clouds.

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* This is treated as a total eclipse in Tables 2, 4, 5.

1901 X 27; 0.228; Grade 1

c Great Slave Lake, Greenland, S. Scandinavia, C. Europe.
Zlatinsky, Mitava, Russia, (181); moon rose out of haze, about a
c = 13.5 half-hour before mid-eclipse; about 10 m. after mid-eclipse, Tycho visible in shadow. 7.5 cm., civil twilight.

1902 IV 22; 1.338; Grade 1

c Antarctic, S. Atlantic, Senegambia, Spain, Sweden, Nova Zemlya, Okhotsk Sea, Pacific, New Zealand.
Khalatov, Tiflis, (185); sky not stated.
b = 2.6 Even with opera-glass, the Mare Serenitatis and Mare Imbrium have the appearance of two black spots. Later, 10.8 cm., various craters; the contours of the principal seas very distinct.
"*Mathematicus,*" Syra, Greece, (186); sky not thoroughly black, yet even the smallest stars visible.
c = 2.8 The color of the moon's disk was very dark, so dark as he has never observed since . . . . October 4, 1884.
Godden, London, Engl., (183); sky gray; astronomical twilight.
d 6.6 e 3 inch; area in shadow invisible. Thinks it as dark as October 4, 1884.
Goodacre, London, Engl., (184); cloudy; astronomical twilight.
d 6.6 e The shadow . . . . very dark, almost black, and quite obscured the eclipsed limb when looked at with a binocular and 3 inch refractor.
Zlatinsky, Mitava, Russia, (189); fine sky, astronomical twilight.
c = 7.2 7.5 cm.; Aristarchus, Copernicus, Kepler, all the seas.
Weinek, Prague, (188); sky cloudless throughout; twilight.
c = 7.9 3 observers, with 9.76 cm., 6.27 cm., 8.37 cm.; within the umbra remarkably little detail was visible.
Allander, Malmö, Sweden, (182); sky not stated; twilight.
c = 14.4 Could see the various maria with the n. e.
Parr, Florence, Italy, (187); sky not stated; twilight.
c > 20 3 inch; seas, etc., visible.

Grade 1 is a compromise among remarkable discrepancies.

1902 X 16; 1.464; Grade 1

c Arctic O., Khamchatka, Pacific, Antarctica, S. Atlantic, Ashanti, near Marseille, Sweden.
Barnard, Yerkes Observatory, (190); favorable conditions.
c = 1.1 [Had observed 6 total eclipses.] The present eclipse was by far the darkest . . . . . For a portion of the time the eastern and western edges could not be seen with the eye . . . . . Very few details were visible in the telescope [6 inch] during totality. Aristarchus and some of the darker regions could be made out dimly. Tycho and the details in its region were not visible . . . . . No details of the surface were visible with the n. e., though at previous eclipses such have been seen.
Payne, Northfield, Minn., (198); broken clouds.
c = 1.2 5 inch; during the last part, all the prominent features of the surface were easily seen, and many of the lesser ones could be recognized.
O'Halloran, San Francisco, Cal., (197); sky not stated.

c = 1.3 . . . . before long the seas were visible, even without magnifying power . . . . the white streaks so conspicuous at full moon were discernible . . . . coppery hue . . . . revealed lunar topography with unexpected distinctness, especially in a telescope. [4 inch.] The color of the seas closely resembled a dull gray object, such as gray paper, on which light through a red lamp falls. The streaks were discernible, even those around Copernicus, and the latter crater was more conspicuous than Tycho. Aristarchus as usual outshone all other features . . . . .

Johnson, Bridport, Engl., (194) ; sky and aperture not stated.
a 3.1 b . . . . Over one fourth eclipsed, but no details of this part visible. As the moon sank down toward the horizon it could be discerned as a faint ruddy circle until 6 o'clock, when the daylight overpowered the totally eclipsed disk. He thinks it a very dark eclipse.

Marckwick, Devonport, Engl., (195) ; clear breaks between showers;
b = 4.4 astronomical twilight. He says nothing of details; would call this a "bright" eclipse.

Godden, London, Engl., (192) ; sky not stated.
a 4.6 b [Just before totality.] In field-glass, margin of eclipsed area very red, the "seas" area black as soot. [Just after totality began] margin coppery, "seas" as black as before.

Crommelin, Greenwich, (191) ; weather conditions perfect; there was
——— not the slighest difficulty in tracing the moon's limb, even when the sky was quite bright with twilight. He followed the eclipsed disk of the moon low down, even through London smoke . . . . was not a very dark eclipse.

Howe, Chamberlin Obsy., (193) ; one haze cloud mentioned.
——— First observation, 20 inch, the eclipsed portion was totally invisible. Later, the whole became visible, in 5 inch and to n. e., before visible in 20 inch. Nothing about details.

Amateur observers in Mexico City, (196) ; good weather; aperture not
——— stated. During the totality it was possible to observe the details of the lunar surface.

Wilson, Goodsell Obsy., Northfield, Minn., (199) ; sky not stated.
——— Opera-glass; at the beginning of the totality . . . . across the equator was a dark shadow, in which no detail could be seen at all . . . . not due to clouds. [He makes no other reference to detail.]

Almost all observers mention a dark smear across the moon, especially in the early stages. There is disagreement about the visibility of the eclipsed limb in the early stages.

Grade 1 is a compromise among discrepancies.

1903 IV 11; 0.973; Grade 0

c E. Siberia, Kara Sea, Arctic O.
1.5 to 4.5 Many observers, instruments large and small, generally good conditions, within the area Lisbon, Syra, Kasan, Nassjö, Sunderland. All agree, shadow at first black, later dim. No detail observed by anyone.

1903 X 6; 0.869; Grade 2

c Antarctica, S. Pacific.

Johnson, Shepparton, Australia, (207); night fine and clear.

c = 1.4 Means not stated. A very light one. At mid-eclipse the whole outline of the disk, and, on the shadowed part, considerable detail, were clearly visible.

Bordage and *Garsault,* Réunion, (205); breaks in clouds.

c 2.3 e Opera-glass and spy-glass; at mid-eclipse, Aristarchus. Later, the lunar topography clearly seen—eastern border of Mare Humorum, Grimaldi, Oceanus Procellarum.

Dubiago, Kasan, Russia, (206); troublesome clouds.

e = 2.7 24.4 cm.; 9.6 cm. The craters were hardly visible, and the eclipsed part was dark red.

"Mathematicus," Syra, Greece, (208); sky and means not stated.

——— The eclipse was indeed a bright one, as the whole dark border of the moon was clearly visible.

1905 II 19; 0.410; Grade 1

c Southern Ocean, Antartica, S. Atlantic O.

Rengel, Lyons, (220); break in clouds; astronomical twilight.

c = 3.2 7.5 cm.; shadow ashy gray, no details visible.

Larronde, Cénac, France, (216); sky not stated; astronomical twilight.

c = 3.7 Opera-glass; shadow slate gray; in it there were feebly distinguishable the important details in the form of spots just perceptible; like the ashy light just before the first quarter.

Moye, Montpellier, (218); sky not stated; astronomical twilight.

c = 3.3 Eclipsed part was plainly seen with the n. e., even since the beginning. The rosy hue was evident, but perhaps less strongly than usual. With 2 inch I saw in the shadowed part some features of the lunar topography; Aristarchus was shining in the dark as a little star. The eclipse was a bright one.

Crommelin, Greenwich, (213); sky not stated; astronomical twilight.

c = 3.9 Binocular; could see the limb distinctly, but no markings.

Hanbidge, Hackney, Engl., (215); sky not stated; astronomical twilight.

c = 3.9 2⅛ inch; the eclipsed part was very dark . . . . there was not a trace of surface features. Part of the moon's eclipsed limb showed brightly through the earth's shadow. In fact, I could trace it all round, but disconnectedly.

"Meteor," Worthing, Engl., (217); very satisfactorily observed. Conditions as perfect as could be desired. Astronomical twilight.

c = 3.9 3¾ inch; . . . . when the illuminated portion of the disk was put out of the field . . . . the markings on the lunar surface, as well as the dark limb of the moon, could be very plainly seen.

Caron, Lillebonne, France, (211); sky not stated, astronomical twilight.

c = 4.1 Marine glass; limb visible throughout, but no details.

Chèvremont, Quiberon, France, (212); sky not stated; astronomical twilight.

c = 4.5 6.0 cm.; shadow dark or iron gray; no details visible.

——— *Quénisset,* Nanterre, France, (219); with a telescope, [aperture not stated], the umbra so transparent that it allowed all the features of the lunar surface to be seen. Coloration slate gray.

——— *Aymé,* Douai, (209); at mid-eclipse the part in the umbra was invisible to the n. e.; in telescope, [aperture not stated], bluish gray; like the ashy light at first quarter.

——— *Burnerd,* (210); place and sky not stated. A lunar eclipse always calls forth such contradictory statements. Here we have a number of observers favored with clear skies, and most of them in disagreement as to the intensity of the earth's shadow. . . . . To me the eclipse was a decidedly light one—so much so that the obscured portion of the disk was clearly visible to the n. e. With 2¾ inch o. g. and 6 inch reflector, several craters beneath shadow stood out prominently, especially Aristarchus.

Dennett, (214); place not stated.

——— The 2 inch held in the hand . . . . showed the markings within the shadow even.

W. G. T., Southampton, Engl., (221); fairly favorable, occasional passing clouds.

——— 5 inch; the bright crater Aristarchus was visible through the shadow all the time the eclipse lasted.

Grade 1 is a compromise.

1905 VIII 15; 0.292; Grade 1

c British Columbia, Franklin Str., Greenland.

Benoit, Juvisy, France, (222); superb weather; astronomical twilight.

a 3.9 c 10.8 cm.; the shadow is not very opaque; certain details on the disk are visible, and the limb is perfectly visible.

de Perrot, Puy, France, (225); sky very pure; astronomical twilight.

c = 4.1 No details visible on the eclipsed part, either with an opera-glass or the n. e.

Guérin, Marseille, (224); sky pure; astronomical twilight.

c = 5.4 7.5 cm.; the shadow was black without color, and although the eclipsed part of the moon was quite visible in the instrument, the brilliant mountains, even Tycho, disappeared completely.

Bloch, La-Queue-des-Yvelins, France, (223); astronomical twilight.

——— 4.3 cm.; throughout the duration of the observations the obscured part was visible although very weak, and not one detail of topography was perceived in the shadow, which was colorless.

Quignon, Mons, (226); exceptional sky; astronomical twilight.

c = 6.1 4.0 cm., shadow grayish black, no details visible.

Stuyvaert, Uccle, Belgium, (228); favorable weather; twilight.

c = 7.7 15.0 cm.; the shadow is dark . . . . no lunar configuration is visible in the eclipsed part, the limb is hardly distinct.

Winkler, Jena, Ger., (229); twilight.

c = 14.7 4 inch; the eclipsed part of the moon was almost invisible.

Wuillemier, Galway, Ireland, (230); sky and means not stated.

——— Shadow intensely black and indistinguishable from the sky, limb invisible.

Rey, Marseille, (227), *de Sforza,* Trieste, (227a), report that Tycho

——— was visible, even brilliant; means not stated.

1906 II 8; 1.631; Grade 2

c Antarctica, South Island, Hokkaido, Nova Zemlya, Norway, Great Britain, Canary Islands, S. Atlantic.

A. López, Hacienda Santa Rita, Mexico, (234); clear.

c = 0.8 The peculiarities of the lunar surface (the spots) were perceived with the n. e.

E. López, Chignahuapan, Mexico, (235); sky and aperture not stated.

c = 0.8 The peculiarities of the lunar surface are just visible, like dark spots.

Ross, Glasgow, Scotland, (238); sky almost free from clouds, but a thin misty veil appeared from time to time; first contact at end of darkness, beginning of totality in strong astronomical twilight.

a = 3.6 3 inch; Aristarchus, Copernicus, Kepler, after first contact; Aristar-

b = 7.2 chus, Menelaus, before totality.

Macpherson, Johnsburn, Scotland, (236); perfect weather, astronomical twilight.

b = 7.7 2 inch; during the first stages of totality the lower part of the disk appeared brighter than the upper, and on the lower several of the prominent lunar features were noted.

Blum, Paris, (231); breaks in snow clouds; strong astronomical twilight.

8.5 4.0 cm.; the illumination was like the ashy light, but nevertheless insufficient to allow the lunar details to be seen. Aristarchus entered the shadow and disappeared immediately. The moon disappeared in low haze when ⅔ eclipsed.

Rudaux, Donville, France, (239); breaks in clouds; means not stated.

b = 13.5 The moon continued visible with all its details.

Denning, Bristol, Engl., (232); well seen. Means not stated.

——— From the entering of the moon into the earth's shadow until after the total phase was reached, the outline of the whole disk, with a large number of included details, continued very plainly visible.

——— *Díaz,* Guadalajara, Mexico, (233); sky and aperture not stated.

In the telescope all the large details of the lunar configuration were seen.

Quénisset, Nanterre, France, (237); atmosphere of perfect limpidity.

——— Equatorial, aperture not stated. All the details of the lunar surface perfectly visible.

1906 VIII 4; 1.786; Grade 2

c Lena Valley, E. India, Indian O., Graham Land, S. E. Pacific, Lower California, Alaska.

Harris, Ngaruawahia, New Zealand; (243); clear between showers.

b 1.1 c Aperture not stated. Not the slightest trace of the moon could be seen with or without the telescope for some time on either side of the greatest phase, although the lunar markings were very plain just before the moon began to leave the shadow.

Ward, Wanganui, New Zealand, (244); beautifully clear; aperture
b = 1.1 not stated. Brilliancy of the moon was very remarkable . . . . . Principal markings could be made out by n. e., much faint detail was seen in telescope. Aristarchus, which appeared to be wholly obliterated at half immersion in the dusky hue, now shone conspicuously.

Gale, Waratah, N. S. W., (242); perfectly clear.
b = 1.1 10 inch reflector and 3¾ inch; all the gray plains and Tycho visible to the n. e.

le Cadet, Phu-Lien, Indo-China, (240); good conditions.
c = 1.5 7.5 cm.; disk visible throughout, except at beginning. Shadow unequal, generally red, bright enough in south to see details of surface; a dark zone, concealing all detail, enveloped all the northern seas and the Oceanus Procellarum. Eastward of this it brightened during the second hour of totality and appeared darker on the Mare Nectaris, Mare Fecunditatis and Mare Tranquilitatis.

Díaz, Guadalajara, Mexico, (241); good weather; means not stated.
a-b Details of the globe and the general configuration of its mountains and seas were seen.

1907 I 28; 0.711; Grade 0?

c Texas, Hudson's Bay, Caspian Sea.

E. López, Chignahuapan, Mexico, (245); best atmospheric conditions;
a 9.7 c twilight. During the early part of the eclipse the covered part was invisible to the n. e.; this continued as the dawn came on.

Grade 0, with interrogation point because only observations with the n. e. are reported.

1907 VII 24; 0.620; Grade 1

c Mozambique Channel, Antarctic ice, Antarctica, S. Pacific.

Díaz, Guadalajara, Mexico, (247); breaks in clouds.
c 1.5 e 10.2 cm.; the details of the lunar configurations were completely lost, and not before 10.15 [after mid-eclipse] were we able to observe some of the bright and radiant craters involved in the earth's shadow.

E. López, Chignahuapan, Mexico, (248); bad atmospheric conditions
——— at first, later fine. With telescope [aperture not stated] the aspect and color of the shadow is such that all the peculiarities of the lunar surface are very readily distinguishable.

Constantin, Port-au-Prince, (246); magnificent weather; means not
——— stated. Aristarchus continued visible in the shadow.

1909 VI 3; 1.164; Grade 2

c Persia, Norway, Greenland, Labrador, Mexico, S. Pacific, Antarctic ice, Indian O.

Serrano, Frenda, Algeria, (253); sky not stated.
c = 2.1 4.3 cm.; during totality, all selenographic details easily seen.

Taffara, Catania, (254); sky not stated.

b = 2.6 3.8 cm.; seas, mountains, volcanoes, etc.

Bougourd, Tunis, (250); admirable sky.

c = 2.6 7.5 cm.; seas turned notably dark—Maria Nubium, Humorum, Tranquilitatis, Fecunditatis. Not due to any clouds.

de Roy, Antwerp, (252); breaks between clouds, astronomical twilight.

b = 4.3 4.3 cm.; the N. W. limb was more easily visible, and the principal details of lunar topography were distinguishable, except the Oceanus Procellarum.

Elgie, Leeds, (251); sky not stated; astronomical twilight.

c = 5.1 Although at its first encroachment the shadow was dead black, when the disk was fully eclipsed many features could be perceived by the n. e.

Borelly, Marseille, (249); sky clear.

——— Comet-seeker; Aristarchus remained visible. Many cirques visible in the shadow.

Zlatinsky, Mitava, Russia, (255); excellent atmosphere.

c > 18 9.5 cm.; the lunar details were easily visible in the shadow.

1909 XI 26; 1.372; Grade 2

c Antarctic ice, S. Pacific, near Para, N. Atlantic, Lapland, near Irkutsk, near Shanghai, Gulf of Carpentaria, near Sydney.

O'Halloran, San Francisco, (259); moon shone brilliantly, with no halo near or distant.

c = 1.1 Many of the markings were recognizable without magnifying power, and an opera-glass showed several of the craters.

Ginori, Buenos Ayres, (257); sky most limpid.

b = 2.1 But when half of the lunar disk was covered, ... the general details of the moon were then seen easily across the shadow, with a binocular.

Campariole, Port-of-Spain, Trinidad, (256); sky practically cloudless

c = 3.5 2 inch refractor, prism binocular; the parts first covered by the shadow appeared very dark, but by the time it had crept over about ⅓ of the bright lunar surface, they began to lighten considerably, and the maria stood out well.

1910 V 23; 1.099; Grade 2

c Southern Ocean, Antarctica, Cape Colony.

Campariole, Port-of-Spain, Trinidad, (260); the condition of the atmosphere rendered definition poor, even when the moon was unobscured by clouds.

a 1.2 b 2 inch and field-glass; the eclipse was one of the brightest I have witnessed. Shadow enters Mare Serenitatis . . . . maria, etc., stand out very well.

1910 XI 16; 1.131; Grade 2

c Bay of Bengal, L. Baikal, Alaska, Rocky Mts., W. Mexico.

Amann and *Rozet,* Aosta, Italy, (261); sky clear.

c = 1.1 During totality, to the n. e. the lunar disk appeared of a dark red color, and the principal details could be perceived.

Goudey, Besançon, France, (262); good conditions during totality.

c = 1.1 During totality, to n. e., the moon assumed a dark red color on which the seas stood out in black.

Lafitte, Roanne, France, (263); completely clear.

c = 1.1 During totality the principal spots were visible to the n. e., and especially, the contours of Mare Imbrium and Mare Serenitatis were very distinct.

Nijland, Utrecht, Holland, (264); very clear breaks in snow clouds.

c = 1.2 3 inch; the chief formations of the eclipsed moon remained easily visible.

Other observers agree in describing the brightness of the eclipse.

1912 IV 1; 0.187; Grade 1

c Near Formosa, China, Siberia, Greenland.

Rey, Ajaccio, Corsica, (271); sky not stated.

a = 1.7 The eclipsed part is very dark and almost invisible in an opera-glass.

Libert, Paris, (269); superb sky.

c = 1.9 10.9 cm.; no detail visible; eclipsed part invisible to n. e., or nearly so.

Leroy, Paris, (268); clear weather.

a = 1.9 7.5 cm.; in the shadow of the earth, Tycho was visible like a bright spot standing out in the dark slate gray shadow. Only Tycho seen.

Péneau, Nantes, France, (270); sky and aperture not stated.

a 1.9 c To the n. e., the eclipsed part is almost invisible; in telescope greenish gray.

c = 1.9 *Hauët,* Paris, (267); means not stated; no detail of the lunar surface was visible in the eclipsed part.

Van der Bilt, Utrecht, Holland, (272); weather partly unfavorable, partly very favorable.

c = 2.0 4½ inch; describes the shadow as remarkably dark, with only a ray of Tycho visible in it.

Dennett, Hackney, Engl., (266); eclipse well seen.

c = 2.1 3 inch. The limb within the shadow was easily seen, and some of the objects upon the disk; two rays of Tycho.

Barlow, (265); place not stated; night extremely clear.

——— Binocular and 4½ inch; by putting the bright portion of the lunar disk out of the field of view, the two bright streaks which converge to the east of Tycho from the south, the irregularities of the lunar limb and many of the various markings were plainly visible.

1913 III 21; 1.575; Grade 0

c Close to both poles; through Bay of Bengal and Yucatan.

Ball, Echuca, Australia, (273); sky not stated.

c = 1.6 4½ inch; I should say it was a composite sort of an eclipse, for a part was blue, a part copper color, but the greater part of it was decidedly black.

Jackson, Mannum, S. Australia, (277); ideal weather.

c = 1.7 During totality, there remained visible to the n. e. only a luminous point, not much larger than the planet Mars and of the same color. With a small telescope the whole disk of the moon was visible.

c = 2.3 *Gray,* Eldridge, Cal., (276). I repaired hastily to my telescope house. On the walk thither the eclipse was so thorough that it cost me some trouble to locate the moon, and many on night duty were unable to see the eclipse because of want of knowledge where to look for the moon. I saw the eclipse well. . . . . Used binoculars, finder and telescope. All the instruments revealed the dull, coppery hue of the expanse of the moon's disk. [Apertures not stated.]

Pargoire, Vinhlong, Indo-China, (279); weather and means not stated. Nearly total when the moon cleared the horizon haze.

d = 2.5 The eclipsed part was totally invisible. Later it began to reappear at its eastern limb.

Flint, Madison, Wis., (275); the sky seemed remarkably clear, down to the horizon all around; astronomical twilight.

b = 6.3 Opera-glasses; it was an exceedingly dark eclipse. It is difficult for me to believe that any but a remarkably dark eclipsed moon could have disappeared entirely in the degree of dawn indicated. . . . .

—— *Barnard,* Mt. Hamilton, (274); I think it probable that this was a dark eclipse.

—— *Newton,* Irvine's Landing, B. C., (278); a dark eclipse.

1913 IX 4; 1.435; Grade 0

c Near both poles; near Manzanillo and near C. Comorin.

Kuyper, Medan, Sumatra, (280); sky very pure.

c = 2.8 Means not stated. During totality the shadow appeared of a bluish gray. Later it remained of a reddish brown, very dark.

Schafer, Port Byron, Ills., (281); sky not stated. Civil twilight.

a = 7.0 6 inch; the shadow was very black, and not a trace could be seen of that portion which it then covered.

1914 III 11; 0.916; Grade 2

c Antarctica, S. Pacific.

Nolte, Newton, Mass., (284); very favorable weather conditions.

c = 1.3 At the moment of greatest eclipse, it was light enough to render the chief surface details visible in a field-glass.

Schafer, Port Byron, Ills., (285); the evening was an ideal one.

6 inch; when the shadow had advanced as far as . . . . Mare Serenitatis, ... I could see some of the larger markings, such as Grimaldi, the dark area in Riccioli, the Sinus Iridum, Aristarchus, Copernicus, Plato and Pico.

c = 1.5 At the middle of the eclipse . . . . with a pair of 8-power field-glasses, the maria were plainly visible.

Cordier, Menton, (282); sky not stated.

b = 1.9 With n. e., noted the redness of the disk, and the visibility of the plains and the seas.

Tramblay, Montpellier, France, (286); exceptional sky.

c = 3.0 At mid-eclipse, with an opera-glass, and especially with 7.5 cm., Aristarchus, Kepler, Copernicus white, Grimaldi and Plato dark.
Leboeuf and *Chofardet,* Besançon, France, (283) ; sky not stated.

c = 3.4 Opera-glass and n. e.; limb and principal details quite visible.
Several other observers, with larger telescopes, or who do not state aperture, corroborate the visibility of details.

1917 I 7; 1.369; Grade 2

c Spain, White Sea, near Yokohama, Pacific, near Wellington, Antarctic ice, S. Atlantic, near C. Blanco.
Prior, Hayling Id., Engl., (288) ; sky clear; civil twilight.

b = 6.9 4½ inch and binocular; the lighter formations visible in binoculars
c = 18.7 throughout.
Ellison, (287) ; place not stated; most favorable of weather conditions; so clear that he saw Venus on the horizon edge.

——— 5¼ inch; Proclus was hardly visible, Aristarchus not much more so, Pliny and Menelaus were conspicuous, and a small crater . . . . a point on the rim of Dionysius . . . . shone like a small star for some time after entering the shadow.

1917 VII 4; 1.625; Grade 2

c Lapland, N. Atlantic, Guiana, near Santiago, S. Pacific, Tasmania, near Manila.
de Paolis, Rome, (292) ; splendid weather.

c = 2.8 13.5 cm.; the lunar topography was easily recognizable, even during totality.
Rey, Marseille, (293) ; sky pure.

d = 2.8 With field-glass, a few details visible.
Ellsworth, Lyons, (289) ; at first much cloudiness, later clear; astronomical twilight.

c = 3.8 5.8 cm.; could see certain details of the surface.
Grabowski, Lemberg, (290) ; good weather; astronomical twilight.

c = 3.7 12.2 cm. and 7.2 cm.; the shadow was pretty bright, so that even within it the details of the moon's surface were for the most part clearly visible.
Weber, Leipzig, Ger., (294) ; sky not stated; civil twilight.

c = 4.7 14 cm.; around, but not in, the darkest region, certain details visible.
Nodon, Bordeaux, (291) ; sky very pure; apertures used not stated.

——— The principal peculiarities of the lunar surface remained perfectly visible during the duration of the eclipse.

1917 XII 27; 1.011; Grade 2

c S. E. Pacific, Antarctic ice, Tasmania.
Reichelt, Honolulu, (295) ; sky not stated.

c = 1.0 The dark and light spots and the familiar markings on the moon's surface were almost as easily distinguishable during totality as under ordinary conditions.

1919 XI 7; 0.184; Grade 0

c — N. Pacific, near Bering's Str., Baffin Land, N. Atlantic.
Quénisset, Juvisy, France, (297); clear spell between clouds.
c = 1.1 — 24 cm.; the shadow was very transparent and of a slate gray tone.
Fock, Frederiksvaerk, Denmark, (296); air free of clouds, slightly hazy, a faint ring around moon.
c = 1.3 — 16.2 cm.; the long ray of Tycho in the direction of Longomontanus remained visible during the whole eclipse [till clouds stopped observing].

1920 V 2; 1.224; Grade 2

c — Southern O., Antarctica, S. Pacific.
Bougourd, Tunis, (299); sky not stated.
a 1.9 b — 7.5 cm.; putting out of the field the part still bright, all the lunar geography is easily distinguished.
Raymond, Antibes, France, (306); clear sky.
a 2.2 b — Opera-glass, and telescope, aperture not given. Telescope shows all the details, which are also visible, a little, with the opera-glass.
Perse, Angers, France, (305); sky not stated.
a 2.3 b — 7.0 cm.; the craters are visible, as well as the seas.
Herzog, La Ferrière, Switz., (303); occasional breaks in clouds, aperture not stated.
a 2.4 b — No detail visible, even with the telescope.
a 2.6 b — *Hestin,* Compiègne, France, (304); clear.
c = 3.2 — The contour of the seas in the eclipsed part is visible to the n. e.
Geneslay, Fay, France, (301); sky not stated.
c = 2.9 — 7.5 cm.; toward the middle of totality the red light weakens, the gray predominates, the details of the surface disappear.
Chouard, Melun, France, (300), fine weather.
c = 3.0 — 7.0 cm.; the larger features of lunar relief were very visible.
Roguet, Péronne, France, (307); sky clear.
c = 3.3 — The dark spots of the disk remained clearly visible during the whole duration of the observations, which were made with the n. e.
Hauptmann, Uccle, Belgium, (302); sky not stated.
c = 3.5 — The great visibility of the disk during totality; all the seas were recognizable by the n. e.
de Roy, Antwerp, (308); favorable conditions.
c = 3.5 — All the seas were visible to the n. e.
Bartrum, Hampstead, Engl., (298); almost cloudless.
——— At all times even minute details could be made out in the shadow [but with which of 5 telescopes and several field-glasses, or with the n. e., is not made clear.]
The visibility of details is corroborated by others, who do not state conditions, means, etc.

1920 X 26; 1.404; Grade 2

c — N. Atlantic, near Petrograd, E. Black Sea, Gulf of Aden, Indian O., Antarctica, Pacific near Los Angeles.
McIntosh, Auckland, New Zealand, (309); light clouds, becoming heavier and hiding moon about totality.

a 1.1 b Aperture not stated. Umbra of a slate gray color, like earth-shine on the moon 4 or 5 days old . . . . . . In it I suspected seeing Oceanus Procellarum, Tycho, Aristarchus and Copernicus.

Stephenson, Jhansi, India, (310); weather very fine.

c = 2.1 The chief maria in eclipsed portion visible to n. e.; [this noted several times during the eclipse].

Tomkins, Barrackpore, India, (311); clear, occasional passing clouds.

a 2.8 b The shadow was of a dull copper color, and details were visible in it all over the moon, and especially so with the aid of the telescopes.

1921 IV 21; 1.074; Grade 0

c N. Atlantic, Arctic Archipelago, Bering's Sea.

c = 2.1 *Sanner,* Guadaloupe, (313); at totality, the eclipsed part was no brighter than the ashy light. With a small telescope, like the fingers viewed against sunlight.

Blundell, New Plymouth, New Zealand, (312); sky not stated.

b = 3.2 6 inch; near the S. E. limb . . . . at no time could any object be detected. Grimaldi could be seen with difficulty, but Aristarchus was plainly visible. Tycho and some of its rays were observed before totality, but the latter disappeared entirely later.

1921 X 16; 0.938; Grade 2

c Antarctica, S. Indian O.

Honnorat, Barcellonette, France, (320); sky not stated.

c = 1.1 Prism field-glass; details with difficulty visible; somewhat better during the second half.

Lagarrigue, Rodez, France, (321); sky not stated.

c = 1.2 4.3 cm. and Foucault telescope 12.5 cm.; at first, no details visible; later, certain details visible.

Fabry, Marseille, (316); sky not stated.

c = 1.2 Opera-glass; like the ashy light a little after new moon. The dark spots on the lunar surface are quite easily visible.

16.0 cm.; *Jasse* observing; no mention of details; the limb is weakly visible, disappearing later.

26.0 cm., *Michkovitch* observing; at the middle of the eclipse, the details of the lunar surface and the limb of the moon are readily visible.

Vetter, Yverdon, Switz., (324); sky not stated.

a 1.3 c With n. e. and opera-glasses, the principal configurations in the shadow are easily distinguished.

Croste, Bayonne, France, (314); sky not stated.

c = 1.3 Opera-glass; at mid-eclipse, the shadowed northern part brick-red, allowing the details of the surface to be seen.

Trarieux, Chamboulive, France, (323); sky not stated.

c = 1.3 Seas visible, but not Copernicus, Plato or Tycho, after entry into the shadow.

Curtis, Winchester, Engl., (315); sky perfectly clear most of the time, then haze c = 1.4 6½ inch reflector; during mid-eclipse all maria were conspicuous both in telescope and to n. e. Most of the brightest craters, including Tycho and his ray system, Copernicus and the Alps, were easily seen with the telescope.

Heath, Kingsbridge, Engl., (319); at first, haze and corona; later clear.

c = 1.4 3⅜ inch; all the lunar maria prominently visible in the eclipsed portion. Tycho . . . . . neither it, nor most of its bright streaks, became invisible at any time.

Meyermann, Göttingen, Ger., (322); good air conditions.

c = 1.4 13.8 cm.; even during the maximum phase of the eclipse all seas were clearly recognizable, particularly notable Mare Humorum and Mare Tranquilitatis. Grimaldi was a very noticeable dark spot. Censorinus, Menelaus, Manilius, Aristarchus, Tycho, of which two rays were especially bright, were easy to make out; Copernicus and Kepler, difficult.

Since Kepler, the visibility of the totally eclipsed moon has been laid to refraction of light by the earth's atmosphere into the geometrical umbra; of late years, since the researches of Tyndall, Raleigh I and others on the blue of the sky, scattering of light into the umbra by dust and air molecules has been added. At the time of the Krakatoa sunsets the attention of all was directed to the results of dust in the air; the dim eclipse of 1884 X 4 caused the suggestion to be made by several[1] that the classical explanation of dark eclipses—cloudiness along the terrestrial terminator—should be at least supplemented by opacity due to the same causes which produced the strange twilight glows. Dufour and Johnson[2] called attention to the coincidence of dark eclipses with volcanic dust haze, as in 1816, after Temboro, 1815. The dark eclipse of 1903 IV 11, after the West Indian and Guatemalan eruptions of 1902, brought this explanation to the fore. But other suggestions for the varying brightness of the eclipsed moon have been made; the moon's varying distance, from perigee to apogee; the moon's longitude, whereby, she being near an equinoctial point, vernal or autumnal, the refracted light comes largely from the Arctic and Antarctic polar regions, supposed to have purer and more refractive air, while, near a solstitial point, the terrestrial terminator passes close to the Arctic and Antarctic circles of latitude, and the light comes through more cloudy regions of the atmosphere. This sugges-

[1] I do not know to whom priority should be assigned; S. J. Johnson, Mon. Not. Roy. Astr. Soc., 45, pp. 43-44, 1884-5, and G. F. Burder, Nature, 30, pp. 590-591, 1884, were among the first.

[2] Ch. Dufour, Bull. Soc. Astr. Fr., 1, pp. 58-60, 1887, L'Astronomie, 7, pp. 28-30, 1888.

S. J. Johnson, Mon. Not. Roy. Astr. Soc., 63, pp. 400-402, 1903.

tion seems to be due to Smith,[1] 1825. Finally, the transparency of the air being affected in some way by emanations from the sun, there should be a relation between the brightness of the eclipsed moon and the solar cycle.[2]

The effect of volcanic eruptions being supposed non-periodic and desultory, in a long series of well-reported eclipses it should average out. So the proposed astronomical causes of variation in brightness will be examined first.

The results of table 1 are arranged in table 2. The eclipses are grouped in three columns, headed North, including eclipses in which the moon passed wholly north of the geometrical center of the shadow, Central, in which the moon passed over the center, South, in which the moon cleared the center on the south side. Each group has columns headed Magnitude and Grade. At the foot the magnitudes and grades are averaged. This is a rough arrangement according to the moon's latitude, the center of the shadow lying on the ecliptic.

The footings show that south eclipses, mean grade 1.62, have been during 1860-1922 decidedly brighter than central eclipses, mean grade 1.32, and these again than north eclipses, mean grade 0.64; the mean magnitudes, south 0.77, north, 0.71, show that the difference between north and south eclipses can hardly be laid to differences in the moon's immersion. In this connection 13 pairs of consecutive eclipses are collected in table 3. The footings of this table show that while the mean magnitudes, 0.68 and 0.72, are not far from equal, the mean grades are wide apart, north 0.54, south 1.54.

From these two tables the conclusion lies near that during the period 1860-1922 in general the southern zone of the earth's shadow has been brighter than the central, and this again than the northern.

Credit for first noticing this inequality must be yielded to the French amateur Rudaux (127), whose observations and sketches of 1895 III 10 showed the center of darkness to be displaced northward from the geometrical center of the umbra. This inequality shows itself in a very marked way in the photograph of 1909 XI 26, taken by Metcalf, (258), figures 2 and 3 at end of this paper. For Rudaux's conclusions, see table 1.

Table 4 shows a comparison of the brightness of every *total* eclipse in table 1 with the moon's equatorial horizontal parallax at opposition.

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[1] M. Smith, Phil. Mag., (1) 66, p. 168, 1825.

[2] This idea appears, but without suggestion of novelty, in an unsigned note, Nature, 46, pp. 64-65, 1892.

According to Young's General Astronomy, 1898, p. 259, the mean parallax is 57′ 02″. In the table the 37 eclipses are grouped in three columns, the center column including parallaxes within 02′ of this mean, or from 55′ 02″ to 59′ 02″. This begins with the break—doubtless due to the accidents of observers' reports—between 54′ 48″ and 56′ 11″, and extends to the beginning of 59′, in which there are only two records. (It is rather odd that the observations should be accidentally so condensed into the apogee and perigee minutes of parallax.)

Table 2.—*68 Lunar Eclipses Arranged According to Position of Moon's Path*

North			Central			South		
Date	Magn.	Gr.	Date	Magn.	Gr.	Date	Magn.	Gr.
1863 VI 1	1.22	0?	1862 XII 5	1.42	0?	1860 II 6	0.81	2?
1865 X 4	0.34	1	1870 I 17	1.66	1	1865 IV 11	0.20	1
1869 VII 22	0.56	1	1870 VII 12	1.69	1	1867 IX 13	0.70	1
1871 I 6	0.69	1	1873 V 11	1.44	1	1869 I 27	0.45	1
1878 VIII 12	0.59	0	1877 II 27	1.67	2	1876 IX 3	0.34	1?
1881 VI 11	1.37	1	1877 VIII 23	1.76	2	1880 VI 21	1.07	2?
1885 III 30	0.89	1	1884 IV 9	1.44	0?	1881 XII 4	0.98	2
1887 VIII 3	0.42	0?	1884 X 4	1.53	1	1889 VII 12	0.49	0
1889 I 16	0.70	0	1888 I 28	1.65	2	1892 V 11	0.95	2
1891 V 23	1.31	1	1888 VII 22	1.82	1	1894 IX 14	0.23	2
1892 XI 4	1.10	0	1891 XI 15	1.39	2	1896 II 28	0.87	2
1894 III 21	0.25	0	1895 III 10	1.63	2	1898 VII 3	0.93	2
1898 I 7	0.16	1	1895 IX 3	1.56	2	1899 XII 16*	1.00	2
1901 X 27	0.23	1	1898 XII 27	1.38	2	1903 X 6	0.87	2
1903 IV 11	0.97	0	1899 VI 22	1.49	0?	1905 II 19	0.41	1
1905 VIII 15	0.29	1	1902 IV 22	1.34	1	1907 VII 24	0.62	1
1907 I 28	0.71	0?	1902 X 16	1.46	1	1910 V 23	1.10	2
1909 VI 3	1.16	2	1906 II 8	1.63	2	1914 III 11	0.92	2
1910 XI 16	1.13	2	1906 VIII 4	1.79	2	1917 XII 27	1.01	2
1912 IV 1	0.19	1	1909 XI 26	1.37	2	1920 V 2	1.22	2
1919 XI 7	0.18	0	1913 III 21	1.58	0	1921 X 16	0.94	2
1921 IV 21	1.07	0	1913 IX 14	1.44	0			
			1917 I 7	1.37	2			
			1917 VII 4	1.63	2			
			1920 X 26	1.40	2			
Sums	15.53	14		38.54	33		16.11	34
No. eclipses .	22	22		25	25		21	21
Means	0.71	0.64		1.54	1.32		0.77	1.62

Table 3.—*Comparison of Path-Position and Brightness of 13 Pairs of Consecutive Eclipses*

North			South		
Date	Magn.	Gr.	Date	Magn.	Gr.
1865 X 4	0.34	1	1865 IV 11	0.20	1
1869 VII 22	0.56	1	1869 I 27	0.45	1
1881 VI 11	1.37	1	1881 XII 4	0.98	2
1889 I 16	0.70	0	1889 VII 12	0.49	0
1892 XI 4	1.10	0	1892 V 11	0.95	2
1894 III 21	0.25	0	1894 IX 14	0.23	2
1898 I 7	0.16	1	1898 VII 3	0.93	2
1903 IV 11	0.97	0	1903 X 6	0.87	2
1905 VIII 15	0.29	1	1905 II 19	0.41	1
1907 I 28	0.71	0?	1907 VII 24	0.62	1
1910 XI 16	1.13	2	1910 V 23	1.10	2
1919 XI 7	0.18	0	1920 V 2	1.22	2
1921 IV 21	1.07	0	1921 X 16	0.94	2
Sums	8.83	7		9.39	20
Means	0.68	0.54		0.72	1.54

Table 4.—*Comparison of Horizontal Parallax and Brightness of 37 Lunar Total Eclipses*

H. P.	Date	Gr.	H. P.	Date	Gr.	H. P.	Date	Gr.
53′ 58″	1895 IX 3	2	56′ 11″	1899 XII 16*	2	59′ 13″	1902 X 16	1
58	1913 IX 14	0	20	1917 XII 27	2	23	1884 X 4	1
54′ 00″	1877 VIII 23	2	36	1909 VI 3	2	60′ 03″	1891 XI 15	2
02	1862 XII 5	0?	47	1891 V 23	1	11.5	1909 XI 26	2
06	1898 XII 27	2	59	1873 V 11	1	17	1917 VII 4	2
10	1917 I 7	2	57′ 36″	1921 IV 21	0	25	1899 VI 22	0?
17	1910 V 23	2	58′ 01″	1906 II 8	2	33	1881 VI 11	1
34	1884 IV 9	0?	04	1920 X 26	2	41	1863 VI 1	0?
40	1902 IV 22	1	11	1888 I 28	2	47.5	1877 II 27	2
48	1920 V 2	2	21	1870 I 17	1	53	1895 III 10	2
			31.5	1870 VII 12	1	59	1913 III 21	0
			43	1888 VII 22	1	61′ 19″	1880 VI 21	2?
			54.5	1906 VIII 4	2	28	1892 XI 4	0
						28	1910 XI 16	2
Sums		13			19			17
No. eclipses		10			13			14
Mean grades		1.30			1.46			1.21

The mean grade of 10 eclipses in the apogee group is 1.30; in the middle group of 13, 1.46; in the perigee group of 14, 1.21. In so far as the arithmetic mean averages out errors and non-periodic causes, this would indicate that at middle distances the totally eclipsed moon has been somewhat brighter than at greater or less, near apogee or near perigee. This differs from the anticipation of L. Günther,[1] that dark eclipses occur at perigee, bright at apogee. But the differences are small, considering the coarseness of the grading, and it can only be concluded that varying distance has not caused much difference in brightness.

Table 5 shows a comparison of the brightness of every total eclipse in table 1 with the longitude of the center of the umbra at opposition. The longitudes are in four groups, each in a quadrant of the ecliptic, for the seasons as indicated. The quadrants are not separated by the equinoctial and solstitial points, as it was found by plotting and trial that a quadrant from 82° to 172° gave a mean grade greater than any other; a division based on this comes near, however, to a strict division according to the seasonal points.

The footings for the columns give as average grades, Autumn, 1.25, Winter, 1.89, Spring, 0.91, Summer, 1.33. So that, in the period studied, winter total eclipses have been very bright, spring eclipses only dim, autumn and summer eclipses intermediate and not much different. Then the longitude effect suggested by Smith exists, but its maximum phase is quite 45° away from that which he expected. Jenkins (49) says: ". . . . of the seven recorded eclipses in which the moon disappeared, none was later than June 15: May 15, 1110, June 15, 1601, April 14, 1642, May 18, 1761, June 10, 1816, June 1, 1863 . . . . middle of April and the middle of June . . . . it is only in this period when the earth is approaching aphelion that the phenomenon is possible." This fits in well with the dimness of the spring group of table 5, but must be considered in connection with volcanic dust.

The curve of mean solar radiation published by Kimball[2] shows the mean relative intensity of received solar radiation, as measured at a variable number of stations (all in north temperate latitudes) for every individual month, 1882-1918. This mean is expressed as a percentage of the mean for the like named months for the whole period; *e. g.*, the mean for February, 1900, is divided by the mean for all the Februaries of the period to get the relative intensity. The

[1] L. Günther, Weltall, 1, pp. 101-103, 112-116, 127-131, 137, 1900-01.

[2] H. H. Kimball, Mon. Weath. Rev., 46, pp. 354-355, 1918.

TABLE 5.—*Comparison of the Longitude of the Shadow and Brightness of 37 Lunar Total Eclipses*

Long. 352°-82°			82°-172°			172°-262°			262°-352°		
	Date, Autumn	Gr,		Date, Winter	Gr.		Date, Spring	Gr.		Date, Summer	Gr.
12°	1884 X 4	1	85°	1899 XII 16*	2	180°	1913 III 21	0	269°	1880 VI 21	2?
23	1902 X 16	1	96	1917 XII 27	2	199	1884 IV 9	0?	272	1899 VI 22	0?
34	1920 X 26	2	96	1898 XII 27	2	211	1902 IV 22	1	282	1917 VII 4	2
43	1892 XI 4	0	107.5	1917 I 7	2	212	1921 IV 21	0	290	1870 VII 12	1
53	1891 XI 15	2	117	1870 I 17	1	222	1920 V 2	2	301	1888 VII 22	1
54	1910 XI 16	2	128	1888 I 28	2	226	1873 V 11	1	311	1906 VIII 4	2
64.5	1909 XI 26	2	140	1906 II 8	2	242	1910 V 23	2	331	1877 VIII 23	2
74	1862 XII 5	0?	159	1877 II 27	2	242	1891 V 23	1	342	1895 IX 3	2
			170	1895 III 10	2	251	1863 VI 1	0?	350	1913 IX 4	0
						254	1909 VI 3	2			
						261	1881 VI 11	1			
Sums		10			17			10			12
No. eclipses		8			9			11			9
Mean grades		1.25			1.89			0.91			1.33

curve is drawn amid a cloud of observation points, and its form is unavoidably somewhat arbitrary. As the depressions count in forming the denominators, the curve rises often above 100 per cent. Beside minor variations, there are three very deep depressions, which follow certain volcanic catastrophes, and are named from them:

Krakatoa depression, 1883 VIII to 1886 XII.

Pelée depression, 1902 VII to 1904 X.

Katmai depression, 1912 III to 1924 VI.

On account of the peculiarities of the method, the dates of beginning and ending of these depressions can be only roughly stated; *e. g.*, the Krakatoa depression seems to have been well started by the end of 1882, though Kimball begins it with the month of the eruption.

This curve is copied in figure 1 of this paper.

During these volcanic depressions there were lunar eclipses as shown in table 6.

TABLE 6.—*Relation of Volcanic Haze and Brightness of 10 Lunar Eclipses*

Depression	Date	Path	Magn.	Grade
Krakatoa	1884 IV 9	C	1.44	0?
	1884 X 4	C	1.53	1
	1885 III 30	N	0.89	1
Pelée	1902 X 16	C	1.46	1
	1903 IV 11	N	0.97	0
	1903 X 6	S	0.87	2
Katmai	1912 IV 1	N	0.19	1
	1913 III 21	C	1.58	0
	1913 IX 14	C	1.44	0
	1914 III 11	S	0.92	2

Summaries; Eclipses 1880-1922

	Number	Sum of grades	Mean grade
I. All included:			
In depressions	10	8	0.80
Not in depressions	42	57	1.36
II. Southern excluded:			
In depressions	8	4	0.50
Not in depressions	28	33	1.18
III. Southern only:			
In depressions	2	4	2.00
Not in depressions	14	24	1.73

Taking all the 10 eclipses occurring during depressions, mean grade 0.80, and comparing with the 42 eclipses, mean grade 1.36, not in depressions but in the period 1880-1922 which surrounds the depressions, the eclipses in the depressions average much dimmer than those without. But 2 of those within are southern eclipses, both of grade 2. This suggests a similar comparison, II, of the eclipses in and out of depressions, excluding all southern eclipses, and III, including only southern eclipses.

The results of comparison II are, mean grade of eclipses in depressions, 0.50, without depressions, 1.18; of comparison III, mean grade of eclipses in depressions, 2.00, without, 1.73. So that the effect of volcanic haze has been practically confined to the northern zone of the shadow.

As to the suggested effect of the solar cycle of sunspots, etc.; during the period considered there is no obvious way in which such an effect could be disentangled from the effects of dust.

Dust is continuously blowing into the air from the deserts and seasonal drought areas of Asia, Africa, North and South America and Australia, whence it goes far, as in the trade wind belts of the North Atlantic and on the Pacific to leeward of the loess areas of China.

Then, the number of known volcanic dust eruptions, big enough to send clouds well up toward the stratosphere, is considerable, and in the past there have doubtless been very many great unknown eruptions; an illustration is the great volcanic dust fall of 1907, over the Seward Peninsula and the Yukon Valley, but of unknown origin; this coincides well enough with one of the minor depressions in Kimball's curve. The details of many known eruptions, the height of the cloud and the spread of the ash, are ill-reported. Thus, an eruption ascribed at first to one of the craters of Skaptar Jökull was seen at Reykjavik, Jan. 9, 1873, and "for days thereafter the cloud stood high in the sky." Thoroddsen assigns this to the Kverkfall, which is 162 miles from Reykjavik; whence the cloud must have been over 15,000 feet high to be seen there at all; how much higher it was is unknown; and the spread of the ash outside of Iceland is unknown. This must have been a very important eruption.

The pyrheliometric observations at Arequipa, Peru, showed no effect of the great Katmai depression. Whence we may conclude that probably volcanic dust from either temperate zone has little effect on atmospheric transparency the other side of the equator. As the greatest deserts and a very large number of the dust-producing volcanoes are in the northern hemisphere, it may be that the darkness of the northern part of the earth's shadow is due to desert and volcanic dust.

The observations do not yield any very definite conclusion as to a difference in brightness of the eastern, or sunrise, side of the umbra, and the western, or sunset side. In the scanty allusions to this point, observers frequently disagree about identical eclipses, or record the phenomena in some cases one way, sometimes the other; and some definitely state that no difference was observed.

Figure 1 is an attempt to show some of the preceding relations graphically. The abscissas are time, in years; the date number stands for Jan. 1 in each year, so that the year interval extends to the right of each number. The upper curve is Kimball's radiation curve, with per cents as ordinates. The next (broken) line connects points

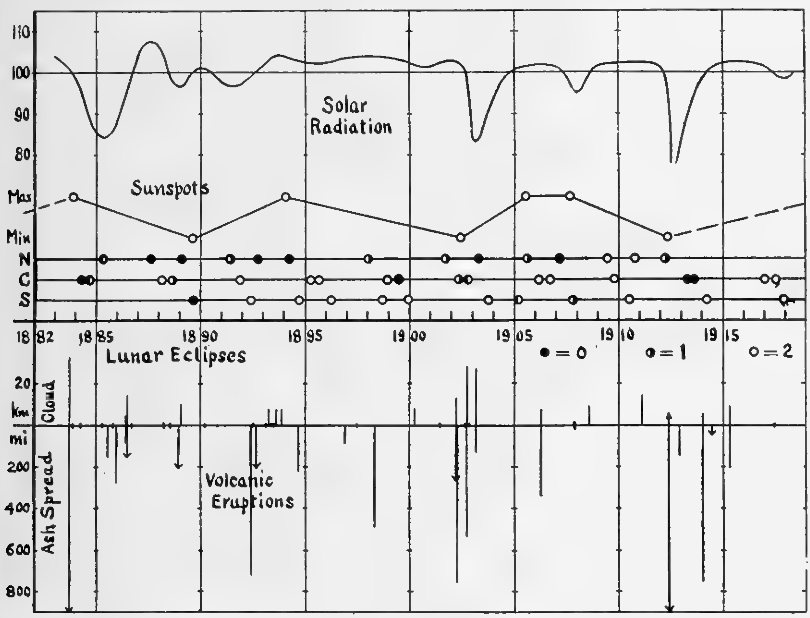

FIG. 1.

representing solar maxima and minima, from Wolf-Wolfers and See; there is no attempt to represent amplitudes of the true sunspot curve. Three lines marked N, C, S, carry circles representing lunar eclipses, north, central and south; a black circle represents grade 0, a half-black, grade 1, a white circle, grade 2. Volcanic eruptions are marked with dots on a horizontal base line; where data could be found, the height of the eruption cloud in kilometers is represented by a line drawn upward from the base, the maximum spread of the ash-fall in statute miles by a line drawn downward; arrowheads on either of these upward or downward lines indicate that the amount represented is doubtless too small. Thus, the Katmai cloud was seen at Cook Inlet, whence it must have been at least 3.4 km. high, to be seen over the earth's curve—but how much higher cannot be guessed; so the upward line for Katmai is tipped with an arrowhead at about 5 km.

In conclusion, thanks are gladly rendered to Dr. Harlow Shapley, Director of the Astronomical Observatory of Harvard College, for the privileges of the Observatory Library; to the Librarian of Harvard University, and to Mr. W. B. Briggs, Assistant Librarian, for privileges granted in the University Library; to the staff of the Boston Public Library; and to Mr. L. Campbell and Miss I. E. Woods, of the Harvard Observatory, for assistance freely and often given.

Professor Alexander McAdie, Director of Blue Hill Observatory, and Dr. Shapley, have been very generous in the matter of conferences. But for selection of data, for methods, results and conclusions, and for errors in this paper, the writer alone is responsible.

SUMMARY

The observational data on lunar eclipses, published by professional astronomers and amateurs for the period 1860 to 1922, have been read, and have been collated, as far as possible, without reference to any theory of the illumination of the eclipsed surface.

A scale of brightness adapted to the data has been devised, consisting of three grades; grade 2, details on the eclipsed surface visible with hand instruments or to the naked eye; grade 1, details visible with apertures of 2 to 6 inches, but not with less; grade 0, apertures of 6 inches or more necessary to show detail. In assigning grades the writer's bias has weighted positive statements of visibility.

This scale has been applied to all suitable data for each eclipse. On account of curious discrepancies in the reports of both amateur and professional observers, the grading has frequently been somewhat arbitrary.

In the hope that the varying masses of air along the ray might prove to have an effect in causing these discrepancies, the relative air mass has been computed for each important report used in grading, and the reports under each eclipse have been arranged in order of increasing air mass; but there seems to be no well-defined connection.

Assuming that the grades thus assigned are significant, the data have been selected and arranged in several sequences, to test the relations of various astronomical and accidental causes to the brightness of the eclipsed moon.

It is found that the position of the moon's path with regard to the center of the shadow is significant; when the moon passes clear of the center on the south side, the shadow is brighter; when it passes over the center, less bright; when it clears the center on the north side, decidedly dim, on the average. This is shown not only for all 68 eclipses, but also for 13 pairs of consecutive eclipses.

In 37 total eclipses there seems to be no very decided effect of distance; on the average, the shadow at middle distances is perhaps somewhat brighter than at perigee or apogee.

In 37 total eclipses there is a marked effect of the seasons, which are implied in the longitude of the shadow; winter eclipses have been bright, spring eclipses dim, summer and autumn eclipses intermediate and not very different, on the average.

The effect of volcanic dust haze in the 3 great atmospheric disturbances named for Krakatoa, Pelée and Katmai has shown itself in the average dimness of 10 included eclipses, as compared with 42 eclipses, 1880-1922, not in the disturbed periods.

If all the southern eclipses occurring in the disturbed periods were removed, the discrepancy between the brightness of the eclipses in the disturbed periods and of those outside them would be increased. It is as if the northern part of the shadow were specially affected by these disturbances, and were in general darker than the southern part.

The average difference between winter and spring total eclipses is perhaps increased by the absence of winter eclipses during the disturbed periods.

During the period discussed there is no discernible relation between the solar cycle and the brightness of lunar eclipses. And, given the effects of north latitudes and volcanic dust hazes as proved, and acknowledging ignorance as to the magnitude, or even the occurrence, of suitably great volcanic eruptions, it is doubtful whether an effect of solar activity can ever be disentangled from dust effects, in records prior to 1880, all the more as the earlier records show greater gaps and fewer detailed statements.

It is to be hoped that in the future eclipses of the moon may be studied with more respect, by astronomers and meteorologists, professional and amateur; and especially, in western North America, in South America, in the Hawaiian Islands, Japan, the Philippines, East Indies, Australia, New Zealand, the islands of the South Sea, and even the Arctic and Antarctic; and that results may be published in accessible scientific periodicals, without biassed and destructive editing. Anybody with good eyesight and a watch can make valuable additions to knowledge, stating where, when, how and what he sees during a lunar eclipse.

NOTE ON FIGURES 2 AND 3

Figure 2 is a reduced half-tone reproduction of the original lunar eclipse photograph made by J. H. Metcalf (258) at Taunton, Mass., 1909 XI 26. The lens used was his 12-inch doublet; scale of plate 93″ = 1 mm.; exposure from 20 h. 13 m. 30 s. to 21 h. 34 m. 00 s., G. M. T.; the telescope was guided on a star and the moon allowed to trail through the earth's shadow between internal contacts.

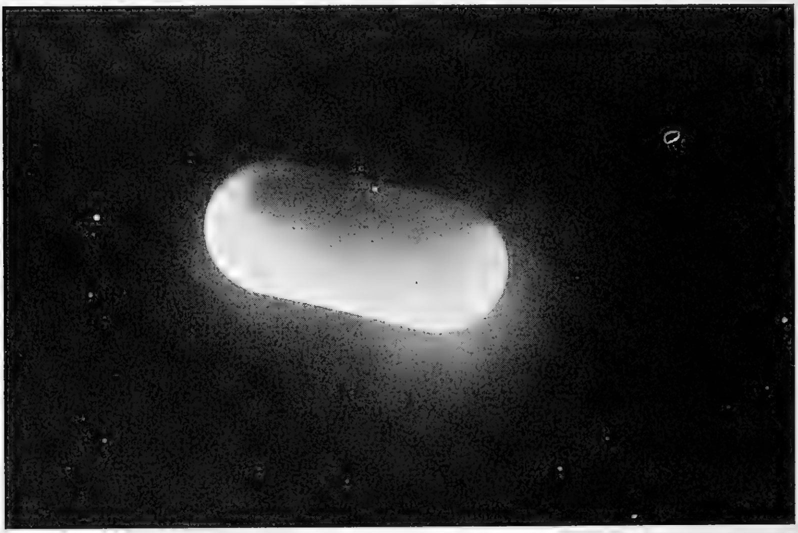

FIG. 2.

Of course the shadow also trailed among the stars a little; and on the plate the moon, and the shadow taken at the moon's distance, are displaced among the stars by parallax; they being seen from Taunton, N. 41° 54′, with the moon's zenith distance changing from 52° to 66°, and not from the center of the earth.

Figure 3 is a diagram on about the same scale as figure 2, roughly showing these geometrical relations. The corners of the rectangle of hour and declination circles were marked approximately on the negative, and a blue print made; on this were drawn the necessary lines, hour and declination circles, ecliptic and orbit, and the outline of the moon trail. On the orbit, the points α and β are the geocentric positions of the moon's center at beginning and ending of the exposure; α' and β' are the same, displaced by parallax. On the ecliptic, a and b are the geocentric positions of the center of the earth's shadow at beginning and end of the exposure; a' and b' are the points where the axis of the shadow pierces a plane at the moon's distance; they are displaced from a and b by parallax. As, at Taunton, the parallax of the moon increased during the exposure, nearly as the sine of the zenith distance, and so not in proportion to the time, the parallactic displacements of corresponding points are greater and differently directed at the end of the exposure. This partly accounts for the departure of the upper and lower limbs of the moon trail from parallelism with the orbit, and for the curvature of these limbs, slight but real in the dim northern limb, easily seen in the southern limb.

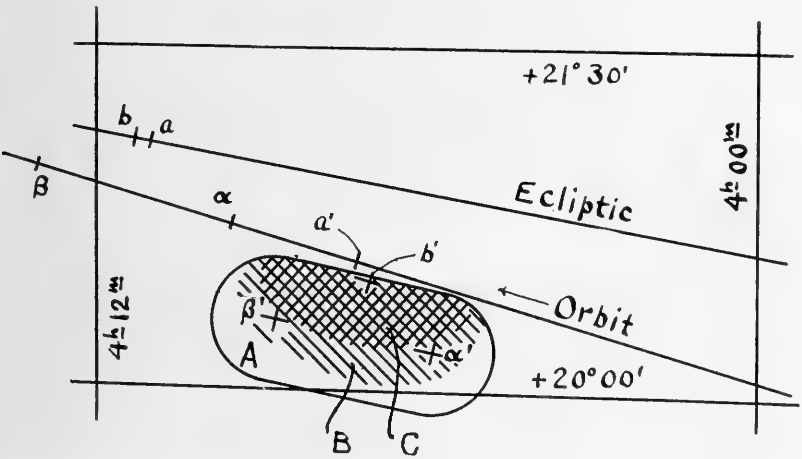

FIG. 3.

Mr. Metcalf also points out another cause—enlargement of the moon's image by irradiation.

The half-tone shows gradations of brightness in the umbra, which are more easily seen in the original. In the diagram these are distinguished as in three zones; A, an outer bright zone; B, an intermediate dimmer zone, single hatched; C, an inner dark zone, double hatched. The boundary of A is, of course, the outer edge of the umbra, not shown; the boundary of B is roughly concentric with the center of the shadow, which lies from a′ to b′; C is markedly elliptical, or flattened on its south side. These peculiarities cannot be due to lunar surface features, which are hard to make out anywhere on the negative; the Mare Frigoris made a faint streak, and faint stripes due to one or two other seas, etc., can barely be traced.

This is the only photograph of a lunar eclipse ever taken by this method, so that we have no similar data about the form of C on the north side of the shadow center. If we suppose that C is oval, with the point of the oval northward, then Rudaux's statement (127), that the center of darkness, 1895 III 10, was displaced northward from the geometrical center of the umbra, is seen to agree well with this photograph.

Thanks are rendered to Rev. J. H. Metcalf, for permission to use the original negative; and to Dr. Shapley, for having it suitably marked, and for conferences regarding its interpretation.

The photograph for figure 2 was kindly loaned by Popular Astronomy.

Additional Note.—After reading proof, I learned that another photograph of the lunar eclipse of 1909 XI 26 was made at the Harvard Observatory, with the 8-inch Draper telescope. A print (kindly handed me by Prof. E. S. King) might easily be taken for a reduction to ⅔ size of Rev. Mr. Metcalf's photograph. It was at his suggestion and by his method that this photograph was taken.—W. J. F.

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1865 X 4	College Romaine, Les Mondes, 10, pp. 183-184, 1866. "Spectrum."
1866 III 30	A. Poey, C. R., 63, pp. 353-357, 1866. "Spectrum."
1867 IX 13	Chacornac, C. R., 65, pp. 501-502, 1867. "Spectroscope."
1870 VII 12	J. Browning, Student and Intellectual Observer, 5, p. 368, 1871. 12 inch and spectroscope.
1876 IX 3	A. T. Arcimis, Mo. Not. Roy. Astr. Soc., 37, pp. 12-13, 1876. 4 inch and spectroscope.
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1877 VIII 23	W. H. M. Christie and E. W. Maunder, Mo. Not. R. Astr. Soc., 37, pp. 469-470, 1877. Greenwich equatorial and 1-prism spectroscope.
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Archives des Sciences (Bibliothèque Universelle)		v. 1859–1879
Astronomische Nachrichten	Ind. 41–150	v. 151–217
Astronomische Rundschau		v. 1–10
L'Astronomie		v. 1–13
Astronomical Journal		v. 1–32
Astronomical Register	Ind. 1–20	v. 21–24
Astronomy and Astrophysics	Ind. 1–3	
Astrophysical Journal	Ind. 1–25	
Boletino de la Sociedad Astronomica de Mexico		v. 1–13
Bulletin Astronomique		v. 1–31, n. s. v. 1–2
Bulletin de la Société Astronomique de France		v. 1–36
Bulletin de la Société Belge d'Astronomie		v. 1–10, 15–21
Ciel et Terre		v. 1–38
Comptes Rendus	Ind. 32–121	v. 122–175
Copernicus		v. 2–3
Cosmos		v. 18–25, (2) 1–7
English Mechanic		v. 6–116
Fortschritte der Physik, (especially III)		v. 16–74
Heis Wochenschrift für Astronomie u. s. w.		v. 1–11, n. f. 1–8
Himmel und Erde		v. 1–26
Jahresbericht der Astronomischen Gesellschaft		v. 1–17
Journal of the British Astronomical Association	Ind. 1–17	v. 18–32
Kleins Jahrbuch		v. 1–23
Memorie della Societa degli Spettroscopisti Italiani		v. 1–2, 5–39, n. s. 1, 2, 5
Monthly Notices of the Royal Astronomical Society,	Ind. 20–70	v. 71–82
Les Mondes		v. 1–31
Nature		v. 1–110
La Nature	Ind. 1873–1912	v. 1913–1921
Observatory		v. 1–45
Popular Astronomy	Ind. 1–16	v. 17–29
Publications of the Astronomical Society of the Pacific,	Ind. 1–25	v. 26–32

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Revista di Astronomia, etc.,..................................v. 1–7
Revista do Observatorio...v. 1–6
Royal Society of Canada, Journal..............................v. 1–16
Sidereal Messenger ....Ind. 1–11
Sirius ....v. 8–55
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SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 76, NUMBER 10

EXPLORATIONS AND FIELD-WORK OF THE SMITHSONIAN INSTITUTION IN 1923

(Publication 2752)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
1924

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

CONTENTS

EXPLORATIONS AND FIELD-WORK OF THE SMITHSONIAN INSTITUTION IN 1923

INTRODUCTION

The field expeditions sent out by the Institution or cooperated in by the members of its scientific staff during the calendar year 1923 are here briefly described and illustrated. The scientific results of many of them will be presented later in the various series of publications under the direction of the Institution; the bulletins and proceedings of the United States National Museum and the bulletins and reports of the Bureau of American Ethnology. That part of the Institution's income from its small endowment of slightly over one million dollars, which is available after defraying administrative costs, does not permit of extensive field operations, but every effort is made to send out or cooperate in as many expeditions as possible with the means at hand. This scientific exploration forms an important part of the Institution's work in the "increase of knowledge," and by means of it much valuable information has been gathered and disseminated and the collections of the United States National Museum have been greatly enriched.

GEOLOGICAL EXPLORATIONS IN THE CANADIAN ROCKIES

During the summer and early fall of 1923 Secretary Charles D. Walcott carried on geological field-work in the Canadian Rockies of Alberta and British Columbia, in continuation of the previous year's work in the main range and the western minor ranges that form the great eastern wall of the Columbia River Valley from Golden south to Kootenay River. His object was to secure data on the Pre-Devonian strata from the Clearwater River southeast to the Bow Valley and along the eastern side of the Columbia River Valley.

The field season was a favorable one for geological work up to the middle of September, despite the intense heat, as the nights were invariably cool and restful.

It was found that the Mons formation which was discovered on the headwaters of the Saskatchewan River at Glacier Lake, extended southwesterly on the western side of the Continental Divide in British

Columbia to the southern end of the Stanford Range between the Kootenay River and Columbia Lake, which is at the head of the great Columbia River, which here flows northwesterly in what is popularly known as the Rocky Mountain Trench.

The valley of the Columbia was found to be largely underlain by the limestones and shales of the Mons formation of the Ozarkian system, and the strata have been greatly upturned, faulted and folded prior to the great pre-glacial period of erosion that cut out the Rocky Mountain Trench for several hundred miles in a north-northwest and south-southeast direction.

The Mons formation is upwards of 3,800 feet in thickness in the Beaverfoot-Brisco-Stanford Range on the eastern side of the Columbia River Valley, and contains four well-developed fossil faunas that indicate its position to be between the Upper Cambrian and the Ordovician systems of this and other portions of the continent (fig. 5).

A great development of Lower Ordovician was discovered near the head of Sinclair Canyon, and cliffs of massive Upper Cambrian limestones were recognized at several localities beneath the Mons formation. Collections were made of corals and other fossils from the Silurian limestones that occur above the Ordovician shales.

This is a wonderful region for the geologist to work in as the numerous canyons and mountain ridges give access to many of the formations from base to summit. Beneath the great series of limestones, shales and sandstones there are 16,000 feet or more of older stratified rocks that form the main range of the Rockies which are so wonderfully exposed along the line of the Canadian Pacific Railway from Banff westward over the Continental Divide to the central portions of the beautiful Kicking Horse Canyon east of Golden.

It was intended to review some of the work of 1921-22 north of Lake Louise near Baker Lake, but a heavy snow storm drove the party back to the railway on the 18th of September, just after a day of taking photographs. The coming of the storm was indicated by the presence of large numbers of mountain sheep and goat in the upper limits of the forest, as well as the presence of black and grizzly bear lower down on the mountain slopes, and wisps of vapor trailing to leeward from the mountain peaks. When the mists and clouds broke away four days later, a thick mantle of snow covered the ridges and peaks well down into the forest covered slopes. A few of the photographs taken near Baker Lake are illustrated by figures 1, 2, and 3.

FIG. 1.—Lake of the Hanging Glaciers. This represents a typical valley glacier that terminates in a lake where the ice front calves or breaks off and floats away in the form of ice floes or miniature icebergs. The main glacier is fed by the snow and ice that fall from the small surrounding glaciers that cling to the slopes of the surrounding mountains. This is a beautiful glacial view just at timber line in one of the wildest spots in the mountains west of Lake Windermere in the Columbia River Valley, British Columbia. (Walcott, 1923.)

FIG. 2.—A mountain view northeast of Lake Louise Station on the Canadian Pacific Railway. Baker Lake (7,321 feet, 2231.4 m.) at the foot of Fossil Mountain (9,655 feet, 2942.8 m.); Ptarmigan Peak (10,060 feet, 3066.2 m.) in the distant center; Redoubt Mountain (9,510 feet, 2898.6 m.) on the left in the distance, and the slope of Brachiopod Mountain on the extreme left. All in the Province of Alberta.

The Lower Cambrian and Pre-Cambrian rocks of Ptarmigan Peak have been thrust eastward and now lie above the much later Devonian rocks of Fossil Mountain. The crest of Fossil Mountain is a syncline or basin of limestone caused by the pressure of the rocks from the westward. (Walcott, 1923.)

FIG. 3.—Upturned Ozarkian and Cambrian strata in northwest section of Sawback Range, northeast of Lake Louise Station on the Canadian Pacific Railway, Alberta. This is a fine geologic section and a Rocky Mountain home of the wild goat, black and grizzly bear, and on the lower slopes elk and deer. (Walcott, 1923.)

FIG. 4.—Ice front of the valley glacier of the Lake of the Hanging Glaciers, showing the moraines above and on the front the curvature of the layers of ice between the moraines. Locality same as figure 1. (Walcott, 1923.)

A side trip was made in August from the Lake Windermere area west up Horsethief Canyon to the Lake of the Hanging Glaciers (figs. 1 and 4). Passing through Wilmer the temperature was above 90°; two days later the snow flakes were sifting down on the tent in the early morning at the camp just below the foot of Starbird Glacier. Climbing up 2,000 feet on a slippery trail, we spent a day at the Lake of the Hanging Glaciers, and were so fortunate as to have a little sunshine in the intervals between snow squalls and whirling clouds of mist. Some of the photographs reproduced here

FIG. 5.—Looking across Columbia River Valley to the west face of Stanford Range between Stoddart Canyon (on right) and Dry-Creek Canyon (on left). At the mouth of Stoddart Canyon the Upper Cambrian Lysell limestones (L.) form a low cliff, and to the left of the canyon foothills of Mons shales and limestones (M.) abut against the cliffs of Silurian limestones, Brisco (Br.) and Beaverfoot (B.). The strike of the Mons and the Silurian strata is indicated by short lines, and the position of the fault between the Mons and the Brisco limestones by a dotted line. A second block of the Mons with Silurian further up Stoddart Canyon is indicated by the letters M., Br. The Red Wall fault and breccia are shown on the face of the high cliffs to the left, which are a short distance south of Sinclair Canyon. (Walcott, 1923.)

give a very imperfect idea of this beautiful lake hidden away in an old glacial cirque which now has a normal glacier fed by the falling ice and snow of the smaller glaciers clinging to the cliffs above. To be fully appreciated both this lake and the Starbird glacier must be visited for a few days.

As a whole the season was a successful one, both from its geologic results and the sketches and photographs of mountain wild flowers obtained by Mrs. Walcott, who sketched in water colors 30 species of wild flowers or their fruit that were new to her collection, a portion

FIG. 6.—Lake Louise, Alberta, after a September snow squall. A reflection of Mounts Victoria and Lefroy from the mirror of the lake. (Mrs. Mary V. Walcott, 1923.)

FIG. 7.—Starbird Glacier at the head of Horsethief Canyon. Purcell Range, about 40 miles (64.3 km.) west of Lake Windermere, British Columbia. (Mrs. Mary V. Walcott, 1923.)

Fig. 8.—A great cluster of 75 blossoms of the Lady Slipper (*Cypripedium parviflorum* Salisb.). Seven miles east of Lake Windermere in the Stanford Range, British Columbia. (Mrs. Mary V. Walcott, 1923.)

Fig. 9.—Labrador Tea (*Ledum groenlandicum* Oeder), which has a range of many thousands of square miles. This particular group of blossoms was from Sinclair Canyon, Brisco-Stanford Range, British Columbia. (Mrs. Mary V. Walcott, 1923.)

FIG. 10.—Bell heather (*Cassiope mertensiana* (Bong.) Don) which carpets large areas in the Canadian Rockies. From Lake of the Hanging Glaciers, British Columbia. (Mrs. Mary V. Walcott, 1923.)

FIG. 11.—Grizzly bear camp up among groves of Lyell's Larch. Southeast of Baker Lake and northeast of Lake Louise, on the Canadian Pacific Railway, Alberta. (Mrs. Mary V. Walcott, 1923.)

of which is exhibited in the main hall of the Smithsonian Institution building. Three of the photographs of wild flowers as growing are reproduced by figures 8, 9, and 10.

During most of the field season the party consisted of Secretary and Mrs Walcott, Dr. Edwin Kirk of the U. S. Geological Survey, Arthur Brown, Paul J. Stevens, packer, and William Harrison, camp assistant.

The Commissioner of the Canadian National Parks, Hon. J. B. Harkin, and the members of the Parks Service in the field, and the officials and employees of the Canadian Pacific Railway, were all most courteous and helpful.

GEOLOGICAL FIELD-WORK IN THE OHIO VALLEY

The field-work for 1923 of Dr. R. S. Bassler, curator of paleontology, United States National Museum, was limited to three regions of the Ohio Valley, namely, the Central Basin of Tennessee, the Knobstone area of southern Kentucky and the Niagaran plain of southwestern Ohio. The stratigraphic and paleontologic studies in the Central Basin of Tennessee, commenced two summers ago, were continued this year in cooperation with the Geological Survey of Tennessee. In previous field-work the geology of the western side of the Central Basin, particularly an area of about 250 square miles just south of Nashville, was studied and mapped. This season's work was concentrated upon the Hollow Springs quadrangle, an area of similar size located on the opposite side of the Central Basin and upon the adjacent Highland Rim. This Highland Rim, a plain area underlaid by very gently undulating strata, is a possible source of oil, so that State Geologist Wilbur A. Nelson suggested that in addition to the usual stratigraphic studies, a structural contour map be made of the quadrangle for use in locating oil areas. Therefore during the geologic mapping special attention was paid to the accurate determination of the top of the Chattanooga black shale, a widespread oil shale formation separating the Mississippian limestones above from the Ordovician limestone below. Sufficient observations were obtained to make it possible to draw on the map the structural contours or lines of equal elevation of the oil shale, thereby revealing the slight undulations of the strata. Several anticlines of interest as possible oil reservoirs were discovered by this method. The stratigraphic sequence in this region proved to be quite different from the western side of the Central Basin for here the middle Ordovician, Cannon limestone as shown in figure 12 is overlaid directly by the early Mississippian Chat-

FIG. 12.—View of Middle Ordovician-Mississippian unconformity near Hollow Springs, Tennessee, showing the undulating line of contact between the Cannon limestone (C) and the Chattanooga black shale (B). (Photograph by Bassler.)

FIG. 13.—View of Highland Rim in east central Tennessee, dissected by Central Basin stream. (Photograph by Bassler.)

FIG. 14.—Falls of Duck River near Manchester, Tennessee. (Photograph by Bassler.)

FIG. 15.—Portion of Stone Fort mound near Manchester, Tennessee, an Indian earthwork built largely of black shale. (Photograph by Bassler.)

tanooga black shale, all of the upper Ordovician, Silurian and Devonian strata thus being absent.

The Highland Rim in this part of Tennessee is dissected by many streams which carve out narrow rocky valleys opening into the Central Basin. This in turn gives rise to many rock outcrops and consequent opportunities for collecting fossils. Such areas, although very rough in nature, contain beautiful scenery, as shown in figure 13. The Highland Rim is as a rule a monotonous plain, but interesting scenery upon it is sometimes developed along the streams where erosion has been sufficient to cut through the hard silicious limestone into the softer underlying black shale. In such cases, as shown in figure 14, waterfalls of considerable size are developed. This particular outcrop is also of archeological interest in that the blocks of black slate shown at the base of the falls furnished part of the material with which the Indians built extensive mounds along the river banks. A portion of these mounds known as the Stone Fort is shown in figure 15.

In company with State Geologist Nelson and the late Mr. W. E. Myer, Dr. Bassler visited the Indian earthworks along the Harpeth River west of Nashville in order to study a blue-clay stratum outcropping in the mounds. Elsewhere in Tennessee this blue clay contains mammals of Pleistocene age but here it was underlaid by strata holding human remains. Therefore at first glance it seemed that definite results as to the age of early man in America had been discovered but upon a little investigation it became evident that the Indians had transported this clay from some distance and packed it down into the flat layers resembling geological strata.

The geologic work in Kentucky was financed by Mr. Frank Springer and consisted of quarrying operations in an area of crinoid-bearing strata. Although some specimens were discovered this season, the main object of the work was to uncover the fossiliferous strata so that weathering during the coming year would reveal the crinoids now hidden in the débris.

In southwestern Ohio, in connection with the packing of the Austin collection of fossil invertebrates for shipment to the Museum, Dr. Bassler, through the courtesy of Dr. George M. Austin the donor of this collection, was enabled to study the geology of the Niagaran plain and surrounding areas from which Dr. Austin had secured his specimens. In this way a first hand knowledge of the region was obtained which is now proving very useful in the study and arrangement of the specimens in final Museum form.

EXPEDITION TO THE DINOSAUR NATIONAL MONUMENT, UTAH

The department of geology of the United States National Museum has long been desirous of obtaining a mountable skeleton of one of the large sauropodous dinosaurs to be utilized as a central feature in the main hall devoted to the exhibit of fossil vertebrates. In the latter part of 1922, the opportunity for securing such a skeleton was presented when the Carnegie Museum of Pittsburgh abandoned opera-

FIG. 16.—Sign on the Victory Highway near Jensen, Utah, directing visitors to the Dinosaur National Monument. Erected by the Vernal Chamber of Commerce. (Photograph by C. W. Gilmore.)

tions at the Dinosaur National Monument in northeastern Utah. In the course of their final excavating, the Carnegie collectors uncovered two partially articulated skeletons of *Diplodocus,* which were left *in situ,* since a sufficient amount of such material had already been secured. When this fact and the intention of the Carnegie Museum to cease operations in the region were communicated to the officials of the Smithsonian Institution, plans were formulated for taking up the work, and in May, 1923, Mr. C. W. Gilmore, curator of vertebrate paleontology, was detailed to take charge of such operations as were necessary to secure a mountable skeleton of one of these huge reptiles.

FIG. 17.—View of the quarry at the Dinosaur National Monument. The slope in the center foreground was excavated for dinosaur remains by the Carnegie Museum. The dump may be seen in the lower left hand corner. (Photograph by Earl Douglass.)

FIG. 18.—General view of the region surrounding the Dinosaur National Monument with Green River at right. The arrow indicates the location of the quarry. (Photograph by Earl Douglass.)

The fossil deposit in the Vernal Valley, near Jensen, Utah, now known as the Dinosaur National Monument (see figs. 16, 17, and 18), was discovered by Mr. Earl Douglass in 1909, and has been worked continuously by the Carnegie Museum since that time. The material secured there—some 300 tons—is greater in quantity and finer in quality than the sum of all that has been obtained hitherto in America. The fossil bones are found here in a thick, cross bedded sandstone of variable hardness that is tilted up to an angle of 60°, as is clearly indicated in the accompanying illustrations.

FIG. 19.—View showing the steeply inclined plane of the fossil bearing sandstone, with blocks of fossils being boxed preparatory to shipping. (Photograph by Earl Douglass.)

Mr. Gilmore arrived at the quarry on May 15. A preliminary survey showed that the two skeletons uncovered by the Carnegie collectors had been partially worked out in relief, as illustrated in figures 20 and 21. These are here referred to as No. 355 and No. 340. It was at once decided that No. 355 (see fig. 21), although lacking much of the neck and some other parts, would form the basis of a mountable skeleton, its value being materially increased by its articulated condition, while the preserved parts of No. 340 would serve admirably to replace the missing bones of No. 355.

Regular work in the quarry was begun on May 24 and proceeded continuously up to August 8. The employment of three men with ex-

FIG. 20.—General view of the skeletons of Diplodocus collected by the National Museum. Men are working on specimen No. 355 at the right, and No. 340 is shown near the floor of the quarry to the left. The large plastered blocks on the ledge are portions of the neck of No. 340. (Photograph by Arthur Coggeshall.)

FIG. 21.—Photograph showing a more detailed view of specimen No. 355 as it was uncovered by Carnegie Museum collectors. The squares, 4 feet across, are painted on the rock to assist in properly mapping the bones. (Photograph by Arthur Coggeshall.)

perience in this field, together with the assistance of Mr. Norman H. Boss of the Museum's paleontological force, who joined the expedition on June 5, were largely responsible for the successful outcome of the operations.

The work of quarrying these often fragile bones from the ledge of rock without doing irreparable damage is a slow and tedious operation, involving the skill of both the stone cutter and the miner. Further difficulty is encountered in handling by primitive methods the immense blocks of rock enclosing the bones, with the subsequent arduous work of boxing and transportation. The largest block quarried, containing the sacrum with attached hip bones, weighed nearly 6,000 pounds when ready for shipment. The transportation of the boxes to the railroad involved a haul by teams of 150 miles across country and over a range of mountains 9,100 feet above sea level. However, 34 large boxes having a combined weight of over 25 tons were safely transported.

The expedition resulted in the acquisition of sufficient material for a good skeletal mount of *Diplodocus* which, it is estimated, will exceed 80 feet in length with a height at the hips of 14 feet.

COLLECTING FOSSIL FOOTPRINTS IN VIRGINIA

In September Mr. Charles W. Gilmore, curator of vertebrate paleontology, United States National Museum, visited the farm of Mr. F. C. Littleton, near Aldie, Loudoun County, Virginia, for the purpose of investigating the reported discovery of fossil footprints. In excavations made by Mr. Littleton in the red Triassic shale in quest of flagstone, numerous footprints were to be observed. These occur in four distinct horizons in a vertical distance of perhaps 100 feet. In two instances at least prints were found in successive layers. Three-toed imprints predominate though they vary in size from a length of three to fourteen inches. A few tracks were noticed having four toes, evidently terminated with wide, flat unguals. All of these are probably of dinosaurian origin, but a few small 4- or 5-toed tracks with traces of sharp claws perhaps pertain to some other group.

While as a whole the tracks bear a striking similarity to those from the Trias of the Connecticut Valley, a critical study and comparison of them would be most interesting. They are of further interest as being the first footprints to have been found in the State of Virginia.

Through the courtesy of Mr. Littleton, Mr. Gilmore again visited the locality and with the assistance of Mr. N. H. Boss collected a fine slab, two by twelve feet, on which were the imprints of a 3-toed

FIG. 22.—Slab of footprints from the Triassic shales, near Aldie, Virginia. Presented to the National Museum by Mr. F. C. Littleton.

dinosaur. This slab shows that the animal had a stride of 56 inches. This specimen which weighed in the neighborhood of 1,500 pounds makes a most important and interesting addition to the collection of fossil footprints now on exhibition. A few separate tracks were also secured at the same time.

FIG. 23.—General view of the place where footprints were found on the President Monroe farm near Aldie, Virginia. (Photograph by C. W. Gilmore.)

PALEONTOLOGIC RECONNAISSANCE IN THE GREAT BASIN

Dr. Charles E. Resser, associate curator of paleontology, United States National Museum, was detailed by Secretary Walcott to spend the months of August and September, 1923, in reconnaissance stratigraphic and paleontologic work in the Great Basin Ranges of Nevada and Utah. This work was planned primarily to obtain information and collections of Cambrian fossils to further the work of Dr. Walcott in his monographic studies of the Cambrian and allied formations. As the region to be studied was so extensive and lacking ordinary means of travel, a Ford truck was purchased in advance at Elko, Nevada, the starting point of the trip (fig. 24).

Mr. M. C. Flohr of Washington, D. C., accompanied Dr. Resser and ably assisted about the camp and in making the collections. Dr. Murray

FIG. 24.—Delayed in irrigation ditch, south of Egan Canyon, Nevada, showing difficulties encountered in exploration work. (Photograph by Resser.)

FIG. 25.—Lamoille Creek and Canyon, in the Ruby Range, the most rugged and picturesque in Nevada. (Photograph by Resser.)

O. Hayes, professor of Geology at Brigham Young University, Provo, Utah, joined the party for a week's work near the end of the season in the Wasatch and Bear Lake Mountains.

Passing by the beautiful Ruby Range (fig. 25) the party proceeded to Eureka, Nevada, where the first two weeks were spent in this region made classic by Dr. Walcott's monograph of 1886. Large collections were secured here supplementing those made by Dr. Walcott in the early days when the district was densely populated and the producer of great quantities of silver and gold. Now it is largely abandoned like the other older mining districts, but more knowledge of the geology is necessary because at the present time several large mining companies are making an intensive search to find any ore bodies that may lie beyond the older workings.

A rapid survey was then made of the Schell Creek, Egan and Snake Ranges in eastern Nevada, all typical Basin Ranges where Cambrian beds are brought to the surface at many places. A most excellent and important section was found in Patterson Canyon, 50 miles south of Ely in the Schell Creek Range, but as it is eight miles by very steep road from the nearest water and 50 miles from the nearest gasoline station, through a wide desert (fig. 26), only one trip could be made to it from the spring at the Geyser Ranch.

A large collection of Cambrian fossils was secured along the Lincoln Highway just west of the summit on Schellbourne Pass. Thousands of tourists pass this way each season, for the party was joined in its camps along this highway invariably by numerous other parties representing every type of American citizen.

In the drier portions of the world the universal and absolute control exercised by water on the position of man's habitation and manner of living is the more apparent. In the Great Basin one finds no dwellings except where water can be secured and the size of the unit of dwellings is determined altogether by the amount of water. Thus one may find a single individual at a small spring, a small ranch at the end of a small stream and a large ranch or groups of ranches where the stream carries more water. The copper ores from the Ruth-Kimberley District must be carried 30 miles across Steptoe Valley to the concentrators and smelters at McGill, situated on Duck Creek, the largest stream in this region. To conserve the water supply the ranches formerly depending on this stream have been abandoned and the water is piped to the plant to avoid the loss in the natural stream bed. The higher ranges catch the greater amount of snow and rain and so the denser populations are located along their foot.

FIG. 26.—Typical desert view along Overland Trail in Steptoe Valley, Nevada, showing flood water after a storm. (Photograph by Resser.)

FIG. 27.—Early morning picture of the Smithsonian camp in Blacksmith Fork Canyon, known for the excellent section studied here by Dr. Walcott. (Photograph by Resser.)

The last two weeks were spent in a brief study of certain sections in the Wasatch and Bear Lake Mountains in Utah. These ranges form the western edge of the great Rocky Mountains and offer many complicated problems in structure and stratigraphy. These mountains are higher and consequently catch a heavier rainfall. The well-watered strip, which is the rich agricultural district of Utah, is the result. Cache Valley in the northern part of the state, between two ranges, is densely peopled in its many farming communities and is a region of great beauty. Numerous canyons have been cut by the larger streams around this valley and among them is the Blacksmith Fork Canyon studied some years ago by Dr. Walcott (see fig. 27), with results which proved so interesting that further collections were desirable.

FIELD-WORK OF THE ASTROPHYSICAL OBSERVATORY

In 1918, the Astrophysical Observatory began to undertake the daily measurement of the variation of the sun. The late Secretary Langley used often to express his prevision that the study of the sun's heat, the losses which it suffers in passing through our atmosphere, the variations which it may be subject to, would at length serve to forecast the changes of weather and climate which are so important for the agriculturist, and which in some parts of the world even lead occasionally to periods of disastrous famine. He used to speak of Joseph's seven years of plenty and seven years of famine, in this connection, and of the possibility that in the future the student of the sun might be in a position to emulate that ancient prophet.

Langley's dream received some support when the Smithsonian Astrophysical Observatory discovered the substantial variability of the sun, and confirmed this discovery by its expeditions to Africa. The influence of the solar variation on the weather was studied by Mr. Clayton, at that time chief forecaster of the Argentine Meteorological Service, and he seemed to find that the sun's variations produced notable influence on the weather conditions of Argentina, and, indeed, of the rest of the world. The results of these preliminary studies of Mr. Clayton were published in the Smithsonian Miscellaneous Collections, Vol. 68, No. 3, and Vol. 71, No. 3.

Our previous investigations had been restricted to the summer and autumn seasons which are notably cloudless at our observing station on Mt. Wilson, Cal. These results appeared so encouraging that it seemed incumbent on us to make the necessary observations of the sun throughout the entire year for a number of years, in order to make a groundwork for further studies of the relation of the variation of the sun to the variation of the weather. As is well known, solar observations of this kind require the highest degree of cloudlessness and uniformity of sky. After many inquiries, it was decided to occupy a station near the city of Calama, on the edge of the Nitrate Desert of Chile. This station was first set up in July, 1918, and continued until July, 1920, when, by the advice and financial assistance of Mr. John A. Roebling, it was removed to the top of Mt. Montezuma, about ten miles south of the former location and high above the dust and smoke which had hindered to some extent the observations near Calama.

At the same time, also, by Mr. Roebling's assistance, the apparatus which had hitherto been used on Mt. Wilson, Cal., was transferred to the top of Mt. Harqua Hala, Ariz., selected after a long meteorological investigation conducted through the kindness of the Director of the United States Weather Bureau. This station was first occupied in October, 1920, and both stations have reported continuously from their establishment until the present time.

The method of solar observation invented by Langley and developed by the Astrophysical Observatory requires a continuous uniform transparency of the sky for several hours, either in the early morning or the late afternoon. It also requires about twenty-five hours of measurement and computing for each day of observation. In 1919, a brief empirical method, based upon this longer and fundamental method, was devised and applied first at Calama and later at Harqua Hala and Montezuma. In 1922, a still further abbreviation of the methods of computing was devised and was introduced at both stations in the spring of 1923. According to this newest method, the required observations for determination of the intensity of the sun's heat as it is outside the atmosphere can be secured in less than fifteen minutes, and the results can be computed in less than an hour, so that it is now possible and usual to make daily five independent determinations at each station of the intensity of the solar heat as it is outside the atmosphere, reduce these observations by one or two o'clock in the afternoon, and, again by Mr. Roebling's financial assistance, communicate them by telegraph, from the stations at Harqua Hala and Montezuma, to the Smithsonian Institution at Washington where they are received early on the following morning. If it were essential, the matter might be still further accelerated, so that telegraphic reports from these distant observing stations could be had on the afternoon of the same day of the observation.

Now that five independent determinations are usually made daily at each station, the mean results are very accurate. A comparison has been made of the daily determinations at the two stations over the period January to October, inclusive, 1923. It proves that a half of one per cent is the average daily difference between the indications of the solar heat as it is outside the atmosphere, determined at these two stations many thousands of miles apart, one in the Northern, the other in the Southern Hemisphere, one at an altitude of 5,000 feet, the other at 9,000 feet.

The two stations join in indicating the march of the solar heat up and down, and within the past year the fluctuations have ranged over about 4 per cent. During the years 1914 to 1921, the results had run generally at a level of about 1.95 calories per square centimeter per minute. Beginning in 1921, a notable downward march began, and by September, 1922, the monthly mean values were ranging at about 1.91. This lower level continued, with minor fluctuations, for a number of months, and the lowest values were reached in February and March, 1922. After that, there was a gradual increase until in September and early October, 1923, the values had come to an average level of about 1.93. Still more recently, there has begun a slump, so that at latest advices, up to February 1, 1924, the solar heat outside the atmosphere is running at approximately 1.92 calories. It will be of great interest, after two or three years of this steady investigation of the solar radiation, to compare the results with meteorological conditions.

The reader might think it obvious that if the solar radiation falls the temperature would fall also. Nothing so simple as this occurs. For the earth's surface is so complex that its deserts, its mountains, its oceans, and other features, with the circulation of the atmosphere, modify extremely the effects of the solar heat. It is easy to see, for instance, that inasmuch as a quarter of the sun's heat is absorbed in the atmosphere itself, and as the atmosphere has but a trifling capacity for heat compared with the solid earth or the ocean, that its temperature must be almost immediately affected by solar variations, far more directly than the temperature of the ocean or the temperature of the land. But since the atmosphere is in some regions hazy, humid, and cloudy, in other regions dry and transparent, the quantity of solar heat absorbed must vary very much from place to place. So the changes in the solar heat must produce very different temperature effects in the atmosphere in a cloudless desert region at high altitude

FIG. 28.—The Windmill of the Montezuma Station.

FIG. 29.—The Montezuma, Chile, Solar Observing Station.
Living quarters below, observatory in a cave at the top of the mountain.

than they would at a cloudy, humid, hazy region where the air is contaminated, perhaps by the smoke of a great city.

The consequence is that air expansion, due to the increased temperature accompanying increase of solar radiation, takes place in much larger proportion in the humid, hazy regions than it does in the cloudless, clear ones, and so the air must flow from the regions of the former condition to those of the latter. This produces changes in barometric pressures which in turn produce the winds and cyclonic movements which are so familiar. With the changes of season and other variable conditions, the regions which are sources of these cyclonic disturbances move about from place to place. This alters the direction of the winds, and, as is well known, the temperature depends intimately on the prevailing winds at every locality. This may explain why it is that we are not to expect at every station and at every time of the year colder weather when the solar radiation is lower. We may have exactly the reverse, depending on these secondary effects. Consequently the study of the dependence of weather on solar radiation must be very long continued and thorough before it will be possible to hazard predictions based upon the variation of the sun, or even to know for certain that the variations of the sun are of importance for our forecasters. The Smithsonian Institution, however, having developed the methods of measurement of the solar heat, seems in duty bound to continue these careful determinations of it long enough to furnish a first rate groundwork of data from which meteorologists can determine these interesting relations.

Notable improvements have been made at both stations through the enthusiastic work of the directors, Mr. L. B. Aldrich at Montezuma and Mr. A. F. Moore at Harqua Hala. One of the most striking of these is the introduction at Montezuma of a windmill, situated at the very top of the mountain, and furnishing sufficient power to produce electric lights and to charge the storage batteries used about the dwelling-house and the observing station. Some additions have been made to the living quarters at each station in order to add to the comfort of the observers and their families. The accompanying illustrations show the Montezuma station with the windmill as now installed. Readers may compare these with previous illustrations of former Exploration Pamphlets.

An expedition was made by Dr. Abbot to the station on Mt. Wilson, formerly occupied for the measurements of the solar heat, but now reserved for occasional occupation for the study of problems requiring good, cloudless observing conditions not found in Washington. Three investigations were proposed: 1, Further study of the use of the sun's heat for cooking purposes, first reported in the Exploration Pamphlet of 1920; 2, the study of the effects of ozone in the earth's atmosphere; 3, a repetition, with improved apparatus, of the measurements of the heat of the spectra of the brighter stars, first attempted in 1922, in the focus of the 100-inch telescope of the Carnegie Observatory on Mt. Wilson.

Some progress was made with the solar cooker, and oven temperatures up to 175° C. were reached. At this high temperature, the oil circulating system sprung leaks and soaked the insulating material which, thereby becoming combustible, spontaneously took fire. So the experiments had to be discontinued. It is proposed to rebuild the solar cooking apparatus for further experiments another year.

The measurements of ozone in the atmosphere have very interesting aspects. The French observers, Fabry and Buisson, have worked out photographic methods of determining the quantities of ozone. This gas, formed by the action of ultra-violet sun rays upon oxygen, occurs very high up in the atmosphere and is scarcely found in appreciable quantities at the earth's surface. The measurements of Fabry and Buisson indicate that the quantity existing in the higher atmosphere, although small, is sufficient to produce notable absorption, indeed extinction, of the extreme ultra-violet sun rays, and the quantity seems to vary from day to day through a range of even as much as 20 per cent. These variations in the atmospheric ozone would not be of importance meteorologically if the effects were restricted to the ultra-violet regions. For the quantity of solar rays there is small and, besides, the extinction of them by the ozone is always so complete that variations are insignificant. However, in the far distant infra-red spectrum region there is a strong absorption band of ozone exactly where the earth itself sends out rays to space. Those are rays which, cooling the earth, maintain the balance of temperature dependent on the equality of the rays which the earth sends out and those which it receives from the sun.

By comparison of the results of Fabry and Buisson with variations of the sun reported from our stations, it seems likely that there is a dependence of the quantity of atmospheric ozone on the intensity of the sun's heat. If so, we have here an indirect influence on the earth's temperature, depending upon the variations of this infra-red ozone band, for it falls precisely in the only region of the infra-red where otherwise the atmosphere is transparent to the earth's rays. Apparatus was set up at Mt. Wilson for the study of this question, but time did not permit of the actual program of ozone measurements being started this year, so that it is postponed for another season.

By the kind assistance of Dr. E. F. Nichols, of the Nela Research Laboratories in Cleveland, and his colleague, Dr. Tear, a radiometer, an instrument similar in principle to the blackened vanes which revolve in the glass bulb in the optician's show window, was employed for the measurements of the heat of the spectra of ten of the brighter stars. It proved possible to measure them very easily and very accur-

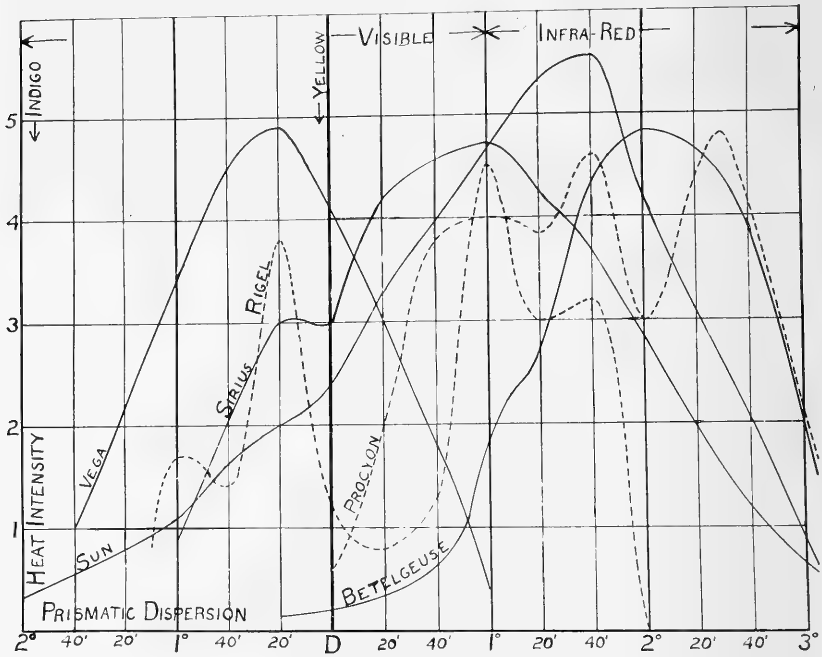


FIG. 30.—Observed Prismatic Energy Spectrum Curves of the Sun and Stars.

ately with this instrument. Indications observed were all about the same magnitude as those which were obtained last year with the bolometer, but owing to the great simplicity and consequent steadiness of the radiometer, the accuracy obtained this year was very much superior to that which was attained last year. The results secured were of very high interest to all astronomers who have seen them. It looks as if this method of studying the stars would prove of much value.

It is possible, in this way, by comparison with the sun, to determine the intensity of star heat nearly as accurately as we can determine the intensity of solar heat. From rough preliminary computations it appears, for instance, that the radiation sent by the bright star Aldebaran, if collected over a *square mile,* would produce 1 calory of heat per minute, whereas the sun's radiation collected over a surface of 1 *square centimeter,* that is to say about three-eighths of an inch on a side, amounts to 1.94 calories per square centimeter per minute.

It is also possible, in this manner, to determine the diameters of some of the stars, providing their distance from the earth is known. In the case of the star Aldebaran, preliminary computations give the diameter as 58,000,000 miles.

Still more interesting are the opportunities offered by the method for estimating the temperatures of the stars. In the case of Aldebaran,

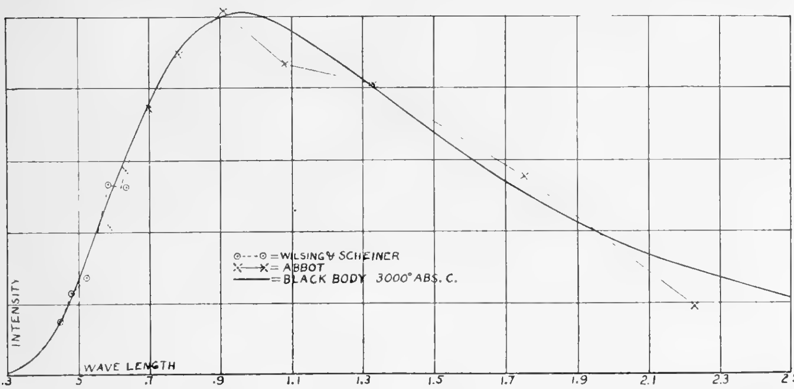


FIG. 31.—The energy spectrum of Aldebaran, as reduced to wave-length scale, and compared to the perfect radiator at 3000° Absolute Centigrade.

the distribution of heat in the spectrum between wave-lengths 0.4 and 2.0 microns, that is to say between a point in the violet and a point far beyond the end of the visible red, fits almost precisely upon the curve of the radiation of the perfect radiator or "absolutely black body" of 3,000° Absolute Centigrade. The fit is, indeed, startlingly close, so that one has no hesitation in assigning to the star Aldebaran the temperature 3,000° Absolute Centigrade. In the case of other stars, including our sun, the fit is less exact, so that one can only give moderately approximate estimates of their temperatures, but the accurate determination of the distribution of the stellar heat in the spectrum cannot but lead to advances in our knowledge of the physical constitution of the stars.

The accompanying figure 30 shows the results as originally observed on the prismatic spectrum of the sun and the stars Rigel, Sirius, Procyon, and Betelgeuse. Figure 31 shows the corrected results in the spectrum of Aldebaran as reduced to the normal wave-length scale and compared with the energy of the perfect radiator or "absolutely black body" at 3,000°.

BIOLOGICAL EXPLORATIONS IN THE YANG-TZE VALLEY, CHINA

On December 15, 1922, Mr. Charles M. Hoy sailed for China to collect vertebrates for the Smithsonian Institution in the region of the Yang-tze Valley. As in previous years his work was made possible by the generosity of Dr. William L. Abbott of Philadelphia. Much delay was experienced in clearing the collecting outfit at the custom house in Shanghai. Consequently it was impossible to begin serious field-work until May 17 when the supplies at last reached Huping College, Yochow City, Hunan. Work was carried on in this general district until June 24, when Hoy wrote as follows:

I am enclosing my official report on the Yochow district, also pages from my catalogues covering all specimens collected to date. I have finished up, for the time being, my work in this district and expect to start, in a few days for Kiangsi. I would have been away before this only my headman stepped on a bamboo spike and poisoned his foot. He has been in the local hospital for over a week but will be discharged tomorrow. When it comes to exasperating delays, this trip seems to be ridden by a sure enough jinx. First one thing then another comes up but I am hoping that the finish will be better than the start. I suppose that you have been reading, in the papers, about the unsettled state of affairs here in China. Things are going from bad to worse and there is, now, practically no central Government. The various Provinces are ruled by their Military Governors who recognize no power but their own and as this power is, generally, not very strong, the lawless element has taken full advantage of the situation. Bandits are everywhere overruning the country and very little is being done to check them. Even those bandits that derailed a train, in Shantung, and captured twenty-six foreigners and over three hundred natives, whom they held for ransom, have gone unpunished. In fact you might say that they were rewarded, for they were enrolled, *en masse,* into the army! Such things just tend to make the bandits, in other parts, all the bolder. Last week a Catholic priest was kidnapped from near Hankow and he is now being held for ransom which is fixed at $1,000,000 (Mex.) or sixteen thousand rifles. Travel, anywhere through China, is, of a consequence, not without a certain amount of danger, but I am going ahead with all my plans and trust to luck in getting through. If I am caught, all that I ask is that nobody ransom me. I don't believe in encouraging the blighters. There was a bit of a scare thrown into the community here, in the disappearance of two of the American professors, last night. At first it was thought that they had fallen into the hands of bandits but it appears that they were out in a canoe when a storm blew up and nothing has been heard of them since. We have searched all day but found nothing but the two paddles and the hat of one of the men. Nothing has been heard of either the men or the canoe but the supposition is that they were drowned. However, there is still the chance of their having been blown out into the current and carried away clinging to the overturned canoe. Thirty boats have been dragging the lake, all day, without success. The paddles came ashore near the spot where the men had last been seen. That spot is one of the most dangerous promontories in the Tung Ting Lake and, annually many boats are wrecked there. (Since writing this the bodies of both men have been recovered.) I have everything ready for my start, except the shipping of the specimens to the United States. My porters arrived today, ten of them, and a right hefty looking bunch they are. They have contracted to carry a minimum load of one hundred pounds at a maximum rate of thirty miles a day, for the magnificent wages of two dollars (U. S. currency) per month, plus their food. Everything in my outfit seems satisfactory with the exception of the auxiliary shells. They seem to be loaded too heavy for about one in every twenty explodes. As a general rule when that happens, the base of the shell is blown off as neatly as if it had been filed. I have several times been temporarily blinded by the powder that blew back through the locking mechanism. The country around Yochow is very well differentiated as to topography, containing mountains, rolling hills, plains and swamp lands. Fully half of the land is not under cultivation and is covered with a dense growth of scrub bamboo, buffalo grass and reeds. Here and there areas of scattered forest growth, mostly pine and other conifers, are met with but as these for the most part have been planted and are not allowed to grow to any great size, they do not support any strictly forest forms of mammals. The district, up to a few years ago, teemed with a great variety of mammal life but floods, droughts, fires and the great increase in hunters have created such havoc that certain species seem to have been exterminated while most of the others have become very scarce. Prices of skins have risen several hundred per cent in the last few years and this fact is mainly responsible for the increase of hunters, for if a man gets only four or five skins a month, he is making far more money than if he worked for wages. Work in the Yochow District has been closed for the present with a total of 169 mammals, representing nineteen species, and 84 birds.

On July 2 Hoy left Huping for a trip through Hunan and Kiangsi. His field books have not yet been received, consequently no detailed account of his route can now be given. He finally arrived at Kuling, Kiangsi, the summer hill resort for foreigners in the Yang-tze Valley. Many interesting specimens were obtained, though no part of the collection has yet reached Washington. About this trip Hoy writes from Kuling, under date of August 12, 1923:

The day after writing my last letter to you, from Iningchow [never received], I had a bad fall and badly wrenched my back. For about a week I was scarcely able to crawl about. Just when my back was getting so I could straighten up I had another accident and shot myself through the left leg with the Colt 45 automatic. The accident was due to a "hang fire." The gun did not go off when the hammer struck and so I lowered the gun to eject the shell when the shell exploded. The bullet struck me on the inside of the leg

FIG. 32.—A typical Chinese farmhouse in the Yochow district, China. (Photograph by Hoy.)

FIG. 33.—Native cheek gun, Yochow district, China. (Photograph by Hoy.)

four inches above the ankle, just missed the big tendon, and came out on the other side just half an inch above the ankle bone. Luckily no bones or important sinews and blood vessels were struck and so the wound although rather painful is not serious. As soon as the accident happened I applied first aid and struck out ahead of my stuff for this place and a doctor. The wound is healing nicely but the doctor says that it may be several months before I get full use of my foot and that I will most likely have a slight permanent limp. However,

FIG. 34.—A widow's arch, Yochow district, China. (Photograph by Hoy.)

I am hoping that it won't interfere with my collecting, but even if I won't be able to do much walking myself I have one man who is a crack shot with the shot gun and another that is fair with the rifle, so I ought to be able to get specimens anyhow. My trip down from Iningchow was rather uneventful except for the above accidents. We were under military guard all the way from there to Kuikiang. The country, it seems, is full of disbanded Northern soldiers who have driven out the natives and occupied their farms. Consequently it is dangerous for even natives to travel through that region. The final explanation given me, as to the reason of the escort, was that it was feared that my guns and ammunition might fall into their hands. We were fired on once, in the night, but aside from a lot of shouting and that one shot, nothing happened. We could never learn who fired the shot but the way things turned out I am convinced that we were mistaken for bandits and the shot was fired to scare

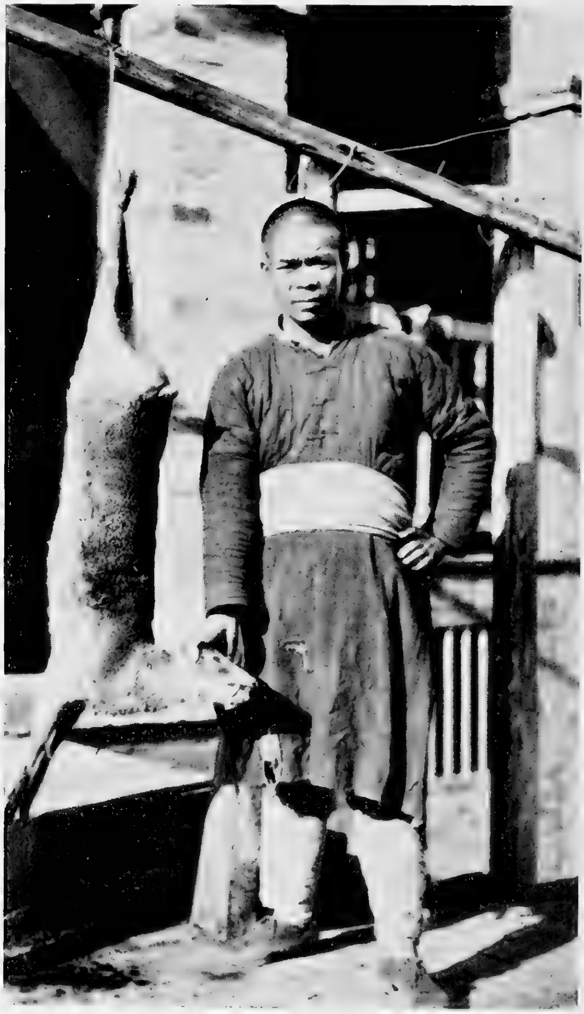


FIG. 35.—Water deer, Yochow district, China. (Photograph by Hoy.)

us off. Owing to the accidents, I have not been able to secure any specimens since the writing of my last letter. My outfit has not yet arrived owing to the heavy rains but as soon as it gets here I plan to send my men out collecting so I will be able to get specimens notwithstanding the fact that I am confined to the house.

The wound was not a subject of serious anxiety. Other conditions, however, soon appeared. These and their subsequent course are described by Dr. W. E. Hoy, Jr., Department of Biology, Presbyterian College of South Carolina, in two letters dated October 14 and 18:

Sometime between the 8th and 12th of August Charles was carried up the mountain to Kuling, suffering from a gunshot wound in the leg. Kuling, as you probably know, is the summer resort for foreigners in the Yank-tze valley. The wound was caused by the accidental discharge of his revolver. The bullet made a clean wound between the tibia and the fibula. No anxiety was felt for his condition. My mother was on the mountain at the time and took care of him. In the next few days my brother developed severe abdominal pains and an attending physician pronounced it appendicitis. He was operated on immediately. This was about the 17th. The operation was a long affair. The appendix could not be found for several hours. The surgeons stated that the appendix was gangrenous and bound down by multiple adhesions. They expressed it as the worst case they had ever operated on. Just after I had written to you the beginning of the week I received further letters from home. My mother stated that Charles had had severe hemorrhages and that he lapsed into coma on the sixth of September. That evening at six o'clock he ceased breathing.

MOLLUSCAN STUDIES ABOUT THE FLORIDA KEYS, BAHAMAS, AND WEST INDIES

The experiments in heredity which are being conducted by Dr. Paul Bartsch, curator, Division of Mollusks, United States National Museum, under the joint auspices of the Smithsonian and Carnegie Institutions required the addition of several elements to render these studies as comprehensive as possible. For that reason transportation was secured on May 1, 1923, on the naval transport *Henderson* sailing from Hampton Roads for Porto Rico. This made possible a number of stops; *viz.*, Guantanamo Bay, Cuba; Port au Prince and Cape Haitian, Haiti; Porto Plata, San Domingo City, San Pedro Macoris, San Domingo; and San Juan, Porto Rico, in all of which places series of minute shells were gathered.

In Porto Rico Governor H. M. Towner was good enough to place an automobile at Dr. Bartsch's disposal, to carry him and his collecting outfit to Guanica Bay at the southwestern end of the island. This gave him an opportunity to see the lay of the land and to understand the zoo-geographic features which govern and underly the distribution of the molluscan fauna. It also showed what a beautiful island Porto Rico really is, and how it has been almost completely bent to human use, with results that in most places very little of the original flora,

FIG. 36.—Upper: A San Salvador mocking bird enjoying a drink from a bird bath made of half a watermelon rind.

Lower: A hand of the junior member of the party, showing the effects of the innumerable bites of the sand fly (*Culicoides furens* Poey), resulting in an endless number of tiny tumid areas. The lizard on the hand was the pet and mascot of the party.

FIG. 37.—Upper: Columbus Bay, San Salvador, in which it is believed the ships of Columbus came to anchor, upon his discovery of America.
Lower: Columbus Point, San Salvador, showing the monument erected by the Chicago Herald in commemoration of Columbus' discovery of America.

FIG. 38.—Upper: A view of the splendid roads which are being built around and across the island of San Salvador.
Lower: A view of the landing in Lake Isabella, showing the type of boat used in lake travel.

and therefore fauna, remains. Frequent stops were made, where suitable places presented themselves, and bags of leaf mould, rich in minute land mollusks, were secured. Thanks to a letter from the governor to Mr. French T. Maxwell, Vice President of the Guanica Central, Dr. Bartsch had splendid quarters assigned to him, and he was granted every facility and assistance to make his week's stay at this end of the island thoroughly available for intensive work. With the aid of a launch owned by Mr. Thompson he was able to comb the south coast from Balena Point to the western extremity of the island, as well as the off-lying islands, for Cerions and other land mollusks, a large series of which was secured.

The return trip was made by the railway that skirts the western and northern shores of the island to San Juan, whence the naval transport *Kittery* carried Dr. Bartsch back to Hampton Roads, arriving on May 27.

This expedition resulted in the securing of about 15,000 land, fresh water and marine mollusks, 48 bats, 1 lizard, some ectoparasites, a collection of ants, and 3 fungi.

A second expedition to the island of San Salvador was undertaken on August 9, at which time Dr. Bartsch and his son left New York on the army transport *St. Mihiel.* They were landed at Cockburn Town on August 12, and spent two trying weeks on San Salvador in intensive collecting. The work was made particularly arduous by the presence of countless numbers of little sand flies, which made it difficult to attend to anything but these little pests in the day time, and absolutely forced one under a cloth screen after sunset. There was only one night when it was possible to collect night flying insects without wearing a superabundance of clothes, gloves securely tied at the wrists, leggins and a cloth head net, but in spite of these trials the island was thoroughly searched for Cerions, and quite a number of new species were secured, but unfortunately not the one that was particularly sought, which group is not represented on the island. Large series of other land mollusks, as well as marine and fresh-water species, were gathered and as many insects and birds as time would permit.

It is interesting to compare present conditions with those described by Columbus in his journal. Not a trace of Indian blood was apparent. The black population consisted of about 700 souls. It was a rather homogeneous, tall, splendid type, actively engaged in pursuits of one kind or another, chief among which is the growing of sisal. Thanks to our Eighteenth Amendment, funds have been steadily pouring into

FIG. 39.—Upper: A native house of San Salvador. These are practically all built of coral limestone and usually thatched with palm.
Lower: A group of native boys. The native population of San Salvador is black, practically unmixed, and of splendid physique.

FIG. 40.—Upper: A sisal field with a primitive sugar mill. Sisal forms the greatest export element of San Salvador. Its fiber is largely used in the making of rope.

Lower: The greatest element in the milk and meat supply of the island.

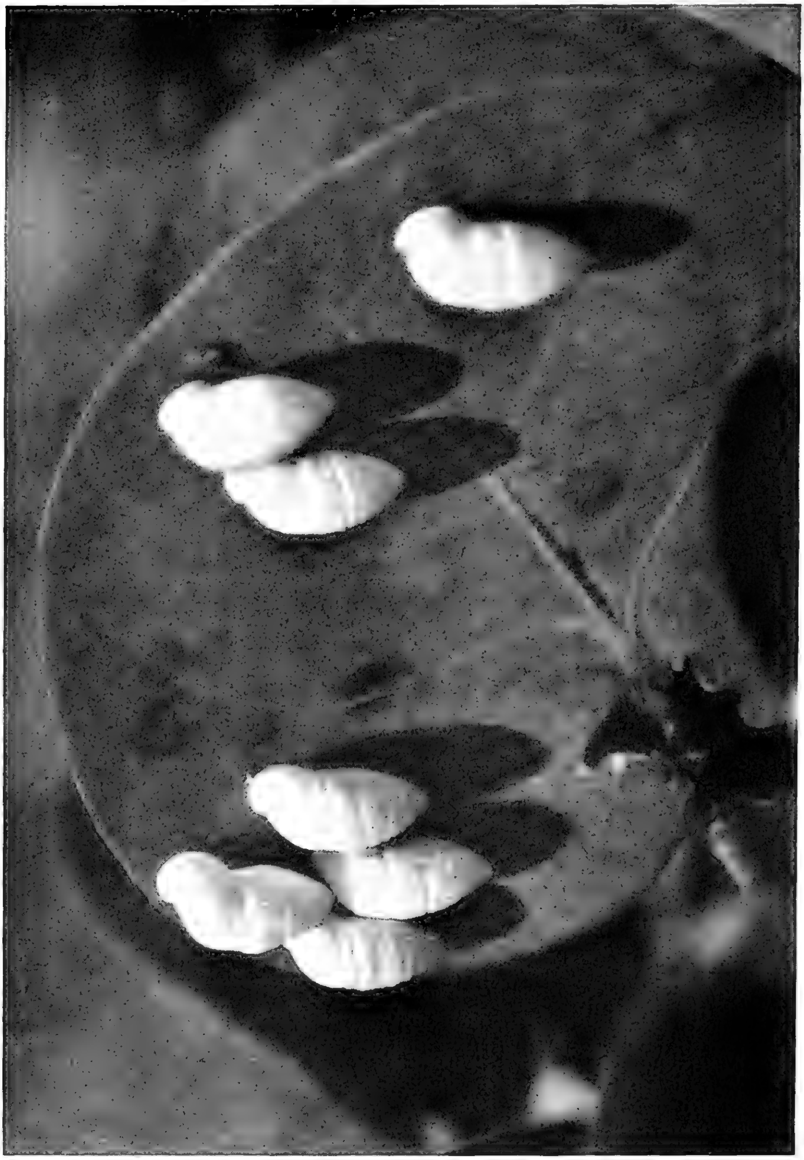


Fig. 41.—A habitat picture of *Cerion coloni* new species, a member of the group used for our experiments in heredity. This species was taken at the base of the Columbus Monument, San Salvador.

the treasury of the Bahamas as import and export duties on wet goods, and this is making it possible for these islands to enjoy a financial uplift which is manifesting itself in the building of splendid roads. The island of San Salvador, for example, is rapidly acquiring an automobile road which will shortly completely encircle it, although there is not a single machine there at the present time, transportation being effected almost exclusively by human carriers, or horseback.

There are two huge lagoons within the island, the larger eastern one of which I have named Lake Ferdinand, and the smaller western one Lake Isabella. These lagoons are supersaline and communicate with the sea by long underground channels. They contain a remarkably modified molluscan fauna characteristic of such places.

The visit to San Salvador resulted in the gathering of approximately 25,000 specimens of mammals, birds, reptiles, batrachians, fish, mollusks, insects and plants.

After two weeks the U. S. Naval transport *Kittery* stopped and carried the expedition to Guantanamo Bay, Cuba. From there the party proceeded to Havana by rail, thence by P. & O. boat to Key West. Here Dr. Bartsch was met by Mr. Mills, the chief engineer of the Marine Biological Laboratory of the Carnegie Institution, and carried by the launch *Valella* to the Tortugas, where a study was made of the Cerion colonies previously placed here. Here, likewise, Dr. Bartsch tried out a new submarine moving-picture camera, with which he secured several hundred feet of excellent films showing marine organisms in their native habitat in depths varying from 10 to 20 feet.

On the return trip the various keys containing Cerion colonies were examined, and the specimens studied. On Newfound Harbor Key 150 Cerions from the hybrid colony were gathered for anatomic study in the laboratories at Washington. The dissections of these specimens are showing some wonderful results.

The *Valella* reached Miami September 9, where Dr. Bartsch took train for Washington.

In addition to the specimens secured, careful notes were taken of the birds observed in the various regions visited.

BOTANICAL EXPLORATION IN THE DOMINICAN REPUBLIC

In continuation of botanical exploration conducted in Hispaniola for several years past, Dr. W. L. Abbott, for many years a generous patron of the Smithsonian Institution, revisited the Dominican Republic in February and March, 1923, giving particular attention to the

Fig. 42.—Tree ferns (*Cyathea arborea*), on the road to Seybo. Perhaps the most graceful of all tree ferns. Unlike most, it commonly grows in open sunny situations at low altitudes and is often planted about houses.

FIG. 43.—Harbor and town of Samaná.

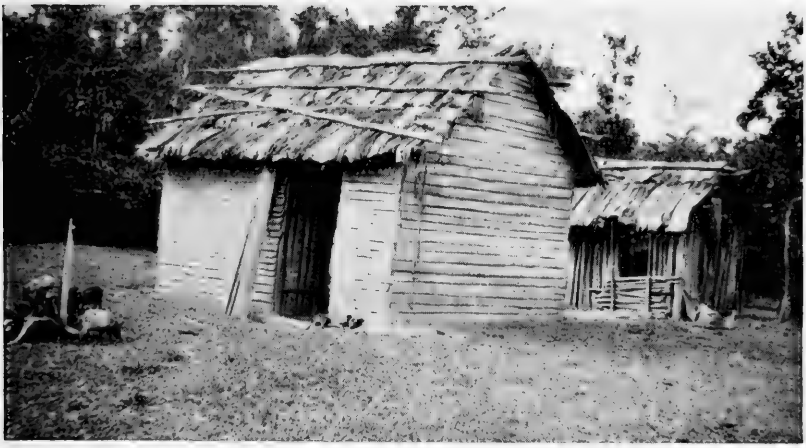


FIG. 44.—A typical house near Jovero. The roof is formed of the sheathing leaf-bases of the royal palm (*Roystonea*).

FIG. 45.—View of forest injured by hurricane of September, 1921. The broken and uprooted trees are densely overgrown with vines and creepers, which flourish in open situations.

FIG. 46.—Trunk of a Santo Domingan "redwood" tree (*Guarea trichilioides*), with numerous epiphytes, chiefly aroids and a freely branched pendent cactus (*Rhipsalis cassutha*).

southern coast of Samaná Bay in the eastern part of the Republic. Field-work was carried on in the vicinity of Jovero, Liali, and Las Cañitas, all located in this region.

Jovero is a small town 21 miles southeast of Samaná, near the river Lajiaguá and on the road running south to Seybo. Supplies are obtainable in small quantities from the several shops which the town affords and good water is obtained from the river, a factor of considerable importance in some of the coastal regions of Hispaniola. The principal product of this district is cacao.

Six miles south of Jovero is a small clearing with three houses, called Liali. From this point as headquarters Doctor Abbott was able to reach the summit of the Cordillera Central in this vicinity at an altitude of about 490 meters. He found the slopes very steep and for the most part covered by virgin forests. Much of the forest of the upper slopes is composed of a low tree called "maho" and scattered royal palms. It may be interesting to note that this locality was the last stronghold of the patriots, held in defense against the American Occupation for five years. This situation had hitherto prevented Doctor Abbott's plan of exploration locally. Peace was, however, made in June, 1922, and the chiefs were given positions in the Dominican Government; consequently the region was quite safe during his present visit.

Las Cañitas is a small village farther west on the south shore of Samaná Bay near the mouth of the Río Catalina and about 12 miles distant from Samaná. Supplies are scarce here and mosquitoes plentiful, especially in the lowlands.

The collections made consist of over 500 plants, a large percentage of which are ferns. The flowering plants prove to be of great interest, and many of them if not new are at least not represented in the United States National Herbarium.

Doctor Abbott returned to the Dominican Republic in November, and at the present time is exploring in the eastern peninsula of the Republic.

BOTANICAL EXPLORATION IN PANAMA AND CENTRAL AMERICA

In May, 1923, Dr. William R. Maxon, associate curator of plants in the United States National Museum, was detailed to accompany a party from the Department of Agriculture, engaged under the direction of Dr. O. F. Cook in investigating rubber resources in Panama and Central America. In company with Mr. A. D. Harvey he sailed for Panama May 15, being joined there shortly after by other members of the party. Mr. Harvey and Mr. A. D. Valentine served as assistants in Panama and during a short trip in western Nicaragua, and the former also during a fortnight spent in Costa Rica the latter part of July. Travel and incidental expenses were borne by the Department of Agriculture. Unfortunately rains interfered seriously with field-work in both Panama and Nicaragua; nevertheless a general

Fig. 47.—A new clearing in dense lowland jungle near Frijoles, Canal Zone, for banana plantation.

botanical collection of about 4,500 specimens was made, representing more than 2,000 collection numbers apportioned about equally among the three countries visited.

Aside from two days given to collecting in the interesting Juan Diaz region east of Panama City, work in Panama was mostly confined to the Canal Zone, being conducted chiefly from headquarters on the Pacific side, at Balboa, with the courteous assistance of the Panama Canal authorities. Of particular interest were trips to Barro Colorado, a large wooded island in Gatun Lake opposite Frijoles,

FIG. 48.—Biological station at edge of virgin forest, Barro Colorado Island, Gatun Lake, Canal Zone. Large collections of insects have been made from this headquarters.

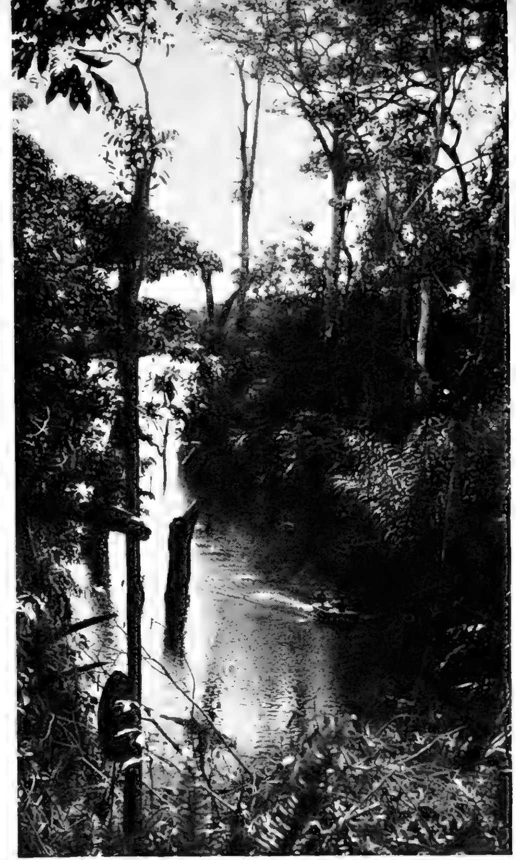


FIG. 49.—View from the biological station. The "stub" in the foreground is one of the innumerable dead trunks occupying the shallow parts of the lake.

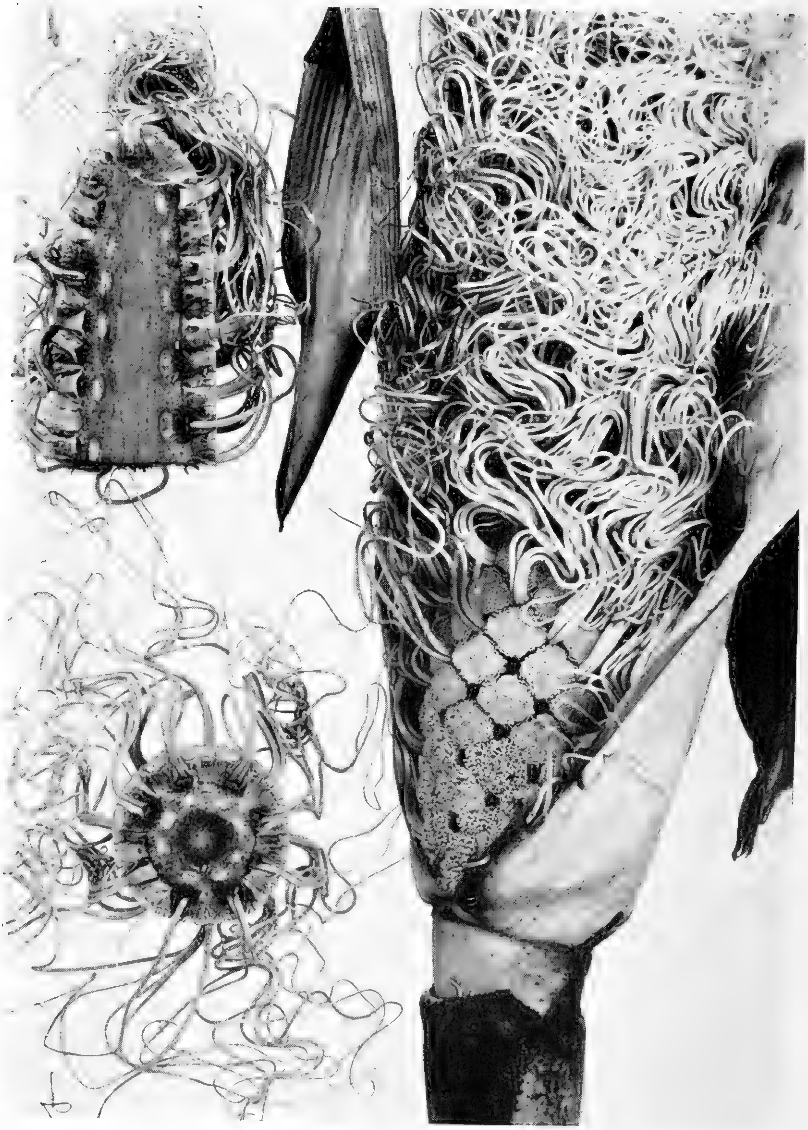


FIG. 50.—Inflorescence of the Ippi-appa "palm" (*Carludovica*), which is not a palm but a member of the family Cyclanthaceae. From the palm-like leaves of this plant most of the cheaper "Panama" hats are made. (Slightly reduced.)

recently set aside as a wild reserve upon representation of the Institute for Research in Tropical America; the virgin forest region at the headwaters of the Rio Chinilla, above Monte Lirio; and the Fort Sherman Military Reservation, which includes the famous old Spanish stronghold, Fort San Lorenzo, at the mouth of the Chagres. All these localities are forested and are rich in palms, and special attention was directed to obtaining material in this difficult group. With the steady clearing of leased land for planting bananas the original forest in the Canal Zone is rapidly disappearing, and with it its characteristic palm associations. These can hardly appear in abandoned cut-over areas for a long time to come, and will therefore have to be sought shortly in unexplored territory adjacent to the Zone. Owing to the killing of thousands of huge trees by flooding in forming Gatun Lake the natural habitat of many rare and peculiar orchids has been destroyed also, and it may be doubted if some of these species will ever be found elsewhere in the region. Fortunately they are largely represented in the truly remarkable collection of living orchids amassed by Mr. C. W. Powell at his home in Balboa as the result of many years of painstaking search in the Canal Zone region and western Panama.

About three weeks was spent in Nicaragua, wholly in the region west of Lake Nicaragua and mainly working from Managua, the capital, which lies picturesquely at a low elevation 90 miles inland from the Pacific coast, flanked by numerous volcanoes. Except for the volcanoes and the low range called the Sierra, given over to coffee production, western Nicaragua is low and almost entirely cleared of forest. Cane and grazing are the main industries. The soil is largely a rich black loam of volcanic origin, and supports a luxuriant growth of tall grasses, the arborescent vegetation being mainly confined to roadsides and abandoned "potrero." The most interesting trips were to the region of Casa Colorada in the Sierra, and to Mombacho and Santiago volcanoes. The material collected indicates a rich flora for the higher mountain slopes, one that would amply repay extended exploration. Returning to Corinto, a day was given to collecting avocados at Chinandega, a locality famous for this fruit throughout the Republic. Notwithstanding the remarkable diversity and excellence of the varieties that are here locally abundant, these seem to have attracted no attention on the part of growers in other countries.

From Corinto Dr. Maxon proceeded by steamer to Puntarenas, the Pacific port of Costa Rica, a little town chiefly notable for its heat, cleanness, and manufacture of tortoise-shell articles. The ascent by

FIG. 51.—Beach and low coastal hills, San Juan del Sur, western Nicaragua.

FIG. 52.—Momotombo Volcano, as seen from the railroad on the way to Managua.

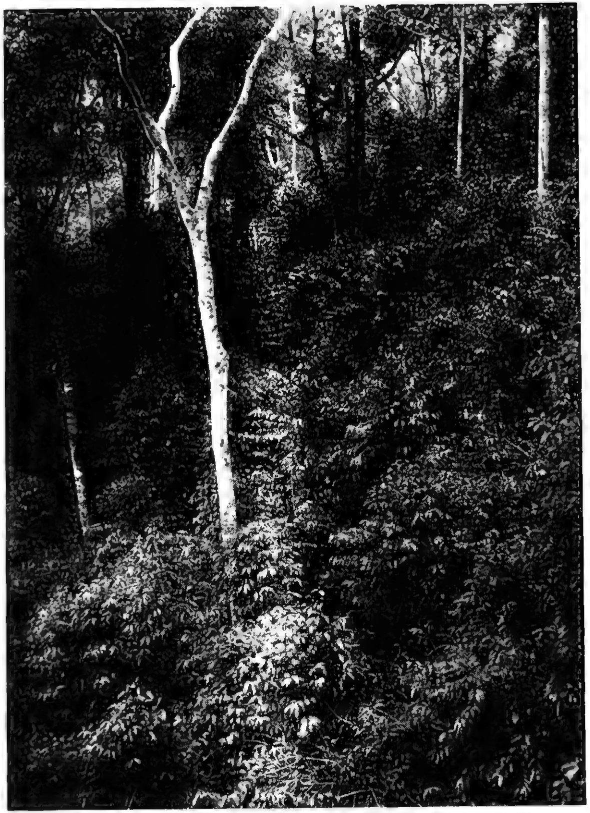


Fig. 53.—Coffee growing under shade, vicinity of Juan Viñas, Costa Rica.

Fig. 54.—A small coffee tree in full flower, vicinity of Cartago, Costa Rica.

FIG. 55.—Partially cleared area in the humid forest region of the Atlantic coastal plain; Rio Honda, Costa Rica.

FIG. 56.—A banana plantation in the Zent District, eastern Costa Rica, near sea level.

rail from this point in the semi-arid coastal plain to the capital, San José, lying at an altitude of 1,140 meters in the cool *meseta central,* is through a region remarkably diverse as to physiography. From San José three principal trips were made: First, to La Palma, a classical botanical locality on the cloud-drenched southwestern slopes of Irazú volcano; next to Santa Clara, in the mountains a few leagues south of Cartago; then to Vara Blanca, lying high up in an almost unexplored region between the volcanoes Poás and Barba. Special attention was here given to ferns and orchids, both groups being

Fig. 57.—Street scene in Puntarenas, the Pacific port of Costa Rica.

extremely abundant both as to species and individuals, and many new and interesting species in these and other groups were collected. The flora of the upper slopes of the interior mountain region appears well-nigh inexhaustible and will long be a most profitable field for botanical exploration.

STUDIES ON EARLY MAN IN EUROPE

During the summer and early autumn of 1923, Dr. Aleš Hrdlička, curator of the division of physical anthropology, United States National Museum, spent three and a half months in revisiting the numerous important sites of early man in western and central Europe, and the institutions in which the skeletal remains of ancient man and the fossil European apes are preserved. Acting at the same time as Director of the American School in France for Prehistoric Studies, Dr. Hrdlička was accompanied on his trip by a number of graduate American students to whom the sites and specimens were demonstrated.

One of the principal objects of the trip was the securing of accurate measurements of the teeth, particularly the lower molars, of the larger fossil apes and early man by one observer, a strictly defined method, and accurate instruments; while a second important object was the taking of photographs of the various sites of early man of which good photographic views were not yet available.

The work began with a re-examination of the Piltdown jaw and skulls which are in the care of Professor Smith Woodward in the British Museum of Natural History, London.[1] The Rhodesian, Boskop, Gibraltar and other early remains in London were also seen once more, and then a day was spent in company with Professor Smith Woodward in a visit to the interesting site where the Piltdown remains were uncovered and where further search was to be resumed during this summer. The results, so far as the Piltdown remains are concerned, were merely to accentuate the conviction that the lower jaw and the skulls do not belong together.

The next visit was to the important Ipswich Museum and to the archeological sites in the vicinity, including that of Foxhall, under the guidance of Mr. Guy Maynard, the Curator of the Museum. A trip to Cromer, kindly arranged by Mr. J. Reid Moir, was undertaken on the following day, to examine the famous "Cromer forest beds." Here Mr. Savin showed the party his invaluable paleontological collections from the Cromer forest beds, and under the guidance of Professor Barnes of Oxford the cliffs bearing worked stones were examined, together with the beach accumulations containing many chipped flints, and also a large private collection of what are supposed to be Tertiary implements. It is in the sites about Ipswich, particularly at Foxhall and also on the beach at Cromer, that worked stones of Tertiary man are believed to have been recovered; but after seeing conditions and noting the divergent views of men who are giving close attention to this subject it was felt that a definite answer to this weighty question is not as yet possible.

[1] Grateful acknowledgments for aid rendered on this trip are due to all those mentioned in this report. Their assistance in giving first hand reviews of the knowledge concerning individual specimens and sites, with personal conduct in many instances to the latter, was of the greatest value.

On the following day the party arrived at Jersey and were met by Professor Marett under whose guidance were seen the originals of *Homo breladensis,* the local archeological collections and the cave of St. Brelade, where work still continues. This site has already given upwards of 20,000 chipped stones of the Mousterian and Aurignacian cultural periods.

Upon his arrival at the British Museum of Natural History, Dr. Hrdlička found awaiting him in care of Professor Smith Woodward a cordial invitation from Professor Eugene Dubois of Haarlem, Holland, to visit him and see the famous remains of the Pithecanthropus as well as the other Java remains in his possession, which for many years were inaccessible. This so far unique privilege, made possible by the fact that Dr. Dubois has at last completed his studies on the precious objects, was taken full advantage of on July 15, Dr. Dubois demonstrating personally and without reserve all the specimens. The remains of, or those attributed to, the Pithecanthropus consist of the now thoroughly cleansed skull-cap, a femur and three teeth, two molars and one premolar. Besides these there is from another locality a piece of a strange primitive lower jaw, and also two skulls with many parts of the skeletons of a later, though yet rather primitive, type of man from consolidated calcareous deposits in still another part of the island.

The examination of the originals belonging to the Pithecanthropus find was in many respects a revelation. It was seen that none of the casts now in various institutions are accurate, and that the same is true of the so far published illustrations, above all those of the teeth and femur. The originals are even more important than held hitherto. The new brain cast shows an organ very close to human. The femur is without question human. When the detailed study of all these specimens is published, which Dr. Dubois expects to occur before the end of the winter, the specimens, though all controversial points may not be settled, will assume even a weightier place in science than they have had up to the present.

In connection with the visit to Haarlem a stop was made in Amsterdam for the purpose of visiting the classic Vrolik Museum, together with the valuable more recent anthropological collections of Professor Louis Bolk, which include a series of the deformed skulls from the Zuyder Zee showing a type that is identical with that of several skulls from the Delaware Valley which at one time were supposed to be very ancient (Bull. 33, Bureau of American Ethnology). The Museum is now directed by Professor Bolk, and in his absence, due to illness, the collections were demonstrated to the party by his two able assistants.

The next visit was to the two museums at Brussels which contain valuable collections relating to early man, namely, the National Museum and the Cinquantenaire. Both these very profitable visits were made under the guidance and with all possible assistance of Professor A. Rutot, who also arranged an excursion to the but little-

Fig. 58.—Gravel beds yielding ancient paleolithic stone implements in the Low Somme Terrace at Montier, suburb of Amiens. Most of the stones showing work of man are found in the very lowest layers of the gravel, as seen in the pit at the right. (Photograph by A. H., July, 1923.)

known cave of Spy and to the equally little-known paleolithic caves of the Lesse Valley.

The next stopping point was Liège, for the re-examination of the Spy skeletons. In company with Professor Charles Fraipont, Dr. Hrdlička visited the house of Professor Maxime Lohest where the precious specimens had been hidden during the war and where they are temporarily preserved to-day. A visit was also paid with Professor Fraipont to the rich prehistoric collections of M. Hamal-Nandein and a participation in the excavations of an early Neolithic site was arranged for the next day, but this was made impossible by rainy weather. Instead of this a very stimulating trip was taken along the archeologically important Meuse Valley from Namur to the French boundary.

Upon entering France the first visit paid was that to the St. Acheul and Montier quarries about Amiens. These gravel and sand deposits are still being worked and they are still yielding Acheulean and Chellean and possibly other ancient implements; but since the death of M. Commont, no one is watching the work and the implements recovered by the workmen are being sold by them to tourists or anyone who cares for them. From Amiens a visit was made to Abbeville, where similar conditions were found to exist.

The next stage was Paris, with a visit to the Laboratoire d'Anthropologie (Professor Manouvrier) and to the Institut de Paléontologie humaine; after which Dr. Hrdlička with all the students proceeded to Bordeaux where they attended (Dr. Hrdlička as a foreign guest) the meeting of the Association Française pour l'Avancement des Sciences. The meeting of the anthropological section of the association was almost entirely devoted to man's prehistory in France and Northern Africa and was very interesting, particularly in its discussions. In connection with the meeting an examination was made of the prehistoric collections in the Bordeaux Museum and of the rich private collections of Dr. Lalanne; while excursions were made to various other collections and prehistoric sites (Bourg, cave Père-non-Père, valley of the Vezère).

On the return trip from Bordeaux, a stop was made at St. Germain where, under the guidance of M. Hubert, the Curator, the richest prehistoric museum of France was examined. This museum belongs to the government. It is located in a large, ancient palace and contains vast prehistoric collections, including most of the precious objects relating to the arts of ancient man that have so far been discovered in France.

The continuation of the journey led to Germany, to the cities of Tübingen, Stuttgart, Frankfort, Heidelberg, Weimar and Berlin, in the institutions of which are preserved highly valuable remains both of early man and fossil European anthropoid apes, all of which, together with most of the sites from which they were derived, were re-examined. In addition, the occasion was utilized for participating in the Congress of the German Anthropologists at Tübingen. Many favors were received from them and from the paleontologists, particularly from Professors Schmidt and Henig in Tübingen, Martin Schmidt in

FIG. 59.—The Mauer site from a distance. The heaps in front are refuse from the quarry. (Photograph by A. H.)

FIG. 60.—Part of the Mauer sand and gravel quarry as it appears today. (Photograph by A. H.)

FIG. 61.—The Ehringsdorf or Kaempfe's Travertine Quarry. View of place where first human lower jaw was found.

FIG. 62. The Ehringsdorf Quarry from a greater distance. First fossil human jaw found at place marked by white spot where the two men stand.

Stuttgart, Wegner in Frankfort, Salomon and his first assistant in Heidelberg, Schuchart in Berlin and Herr Lindig in Weimar.

From Germany the trip led to Bohemia where, to facilitate the work, a special representative of the Ministry of Foreign Affairs, Dr. Novák, together with Professor Matiegka, gave personal guidance to various museums as well as to the great ossuary at Mělník and especially to that at Sedlec, where many thousands of crania and bones from the time of the Hussites are tastefully arranged in the form of a most impressive, spacious subterranean chapel. Under the same guidance visits were paid to the great Moravian caves which have yielded and probably still contain remains of early man as well as those of the cave bear (six complete skeletons) and Quaternary beaver (upwards of 20 finely preserved skulls with many bones); to the Provincial Museum at Brno which harbors the valuable remains of the Předmost mammoth hunters, and to the monastery of Mendel, still full of reminders of the student-monk, including his library and garden. A number of interesting details were learned about Mendel from the excellent abbot of the monastery, among them the fact that Mendel was a Moravian and spoke both the languages (Czech and German) of the country.

The following stage of the journey was to Vienna, where the rich prehistoric and anthropologic collections of the former Hoff-Museum were examined under the guidance of Professor Szombathy.

From Vienna Dr. Hrdlička with some of his students proceeded to Zagreb in Croatia, where in company with Professor Gorjanovič-Kramberger they re-examined the very valuable Krapina remains and visited the locality where they were discovered. This is situated at the head of the very beautiful but little-known Krapinica Valley, and indications were seen that there may be additional sites of ancient man in the vicinity of the original discovery.

From Zagreb the journey led over northern Italy to Lyons where the collections of the University were examined in company with Professor Mayet; this was followed by an excursion under the guidance of Professors Arcelin and Mayet to the prehistoric site of Solutré. Here existed some 15,000 years ago a large paleolithic settlement, the duration as well as the size of which may be seen from the fact that its refuse accumulations are estimated to contain, aside from implements and other objects, the bones of approximately 200,000 late Quaternary horses. New explorations have just recommenced at this site, and they led within three days of the visit to the recovery of no less than five prehistoric Solutrean or Upper Aurignacian skeletons, some in a very good state of preservation.

From Solutré the road led to Les Eyzies, in the valley of the Vézère (Dordogne), which is probably archeologically the richest as well as one of the most picturesque regions of the world. Here under the guidance of Abbé Breuil and M. Peyrony, were visited the sites of Le Moustier, La Madeleine, La Ferrassie, Laugerie Haute and Basse and others of importance, as well as numerous caves showing graven, painted, or sculptured prehistoric animals. Here was also examined the very promising new local museum which is under the

FIG. 63.—Part of excavations at La Quina, Charente, France. (Photograph by Dr. G. G. MacCurdy.)

direction of M. Peyrony and which was officially opened a short time subsequently.

After 10 days spent in the district of Les Eyzies the journey was prolonged southward to Toulouse where, with Count Begouen the local museum with its rich Cartailhac and Begouen collections was examined and from which an excursion was made to a vast cave with splendidly preserved paintings of ancient animals in the Pyrenees.

The last portions of the journey included an eight days' stay with Dr. Henri Martin at La Quina, becoming acquainted with its already important museum and assisting in the excavations; this was supplemented by visits to the prehistoric collections of the museums at

Perigueux, Angoulême and Gueret. Then followed a return to Paris and a final trip to Havre where the very interesting and but little-known prehistoric collections from the maritime district of Havre were examined in the local museum.

The trip resulted in an overwhelming sense of the greatness as well as scientific importance of the field of early man in western and central Europe, and in a keen appreciation of the opportunities for cooperation in this field by American students.

ARCHEOLOGICAL INVESTIGATIONS IN SOUTH DAKOTA

Mr. M. W. Stirling, assistant curator of the division of ethnology, U. S. National Museum, spent the month of June, 1923, in the examination of old village sites on the Missouri River. The region investigated was the 12-mile strip between Grand River and Elk Creek, South Dakota. Much of the success of the exploration was due to the able cooperation of Mr. E. S. Petersen of Mobridge, South Dakota.

During the eighteenth and up to the middle of the nineteenth centuries, the upper Missouri River was the scene of a very considerable shifting of native populations. On the one hand there was a south to north movement and a possible reverse tendency; on the other hand a general east to west movement in which such tribes as the Cheyenne, Sutaro, Arapaho, and others, figured. These tribes before leaving the Missouri River for the nomadic life of the plains were, according to tradition, a sedentary agricultural people, living in earth-lodge villages like those of the Arikara, Mandan, and Hidatsa. The Grand River formed the western pathway for these migrations, and we find the point of intersection of these tribal movements in the vicinity of the junction of the Grand River with the Missouri. To establish the identity of the numerous sites in this region is a complex but interesting task.

In all, 10 of these old villages were visited and excavations carried on in four. Three of these, on the west bank of the Missouri, were identified as Arikara; one being the historic upper village of the Arikara visited by Lewis and Clark in 1804 and later by Brackenridge and Bradbury in 1811. The others were all prehistoric, but from the presence of a few objects of European origin found in each, obviously of post-Columbian age. The fourth site excavated is on the east bank near the town of Mobridge and seems most likely to have been Cheyenne.

There is a close similarity existing between the material culture remains of all of the upper Missouri tribes. Because of this fact,

FIG. 64.—Two specimens of old Arikara pottery showing incised and cord marked designs.

FIG. 65.—Gorgets and balls of Catlinite, and a polished chalcedony pendant. Arikara.

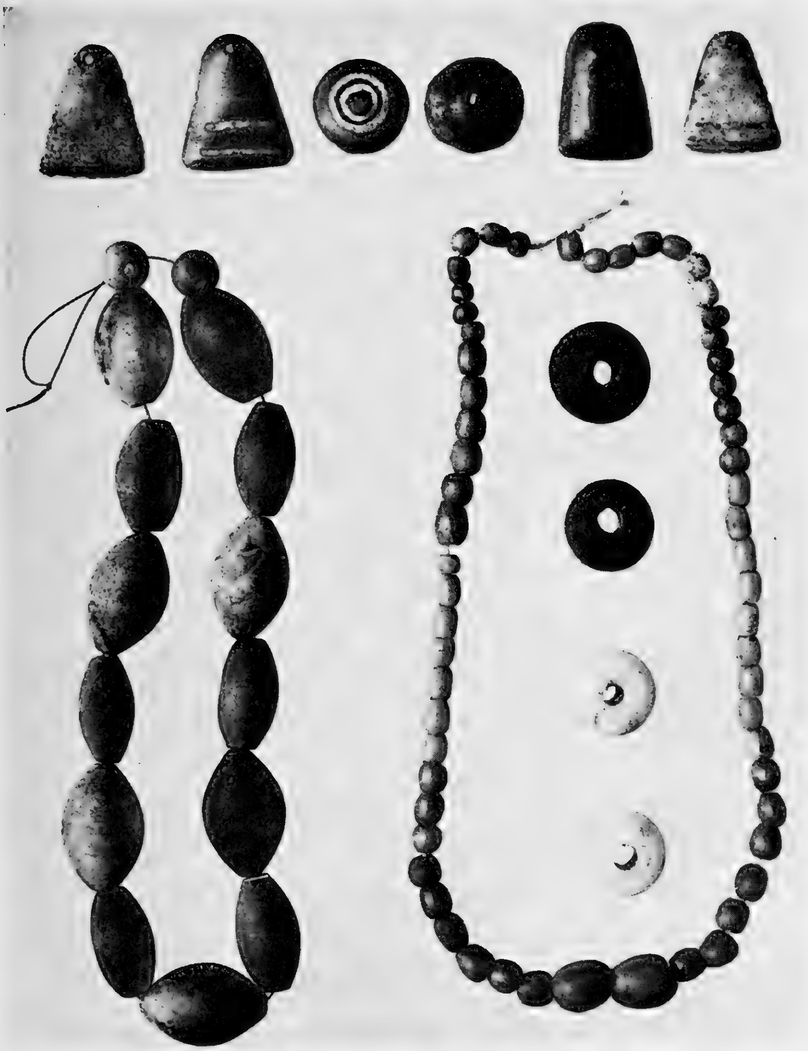


Fig. 66.—Glass beads and ornaments of native manufacture. Arikara.

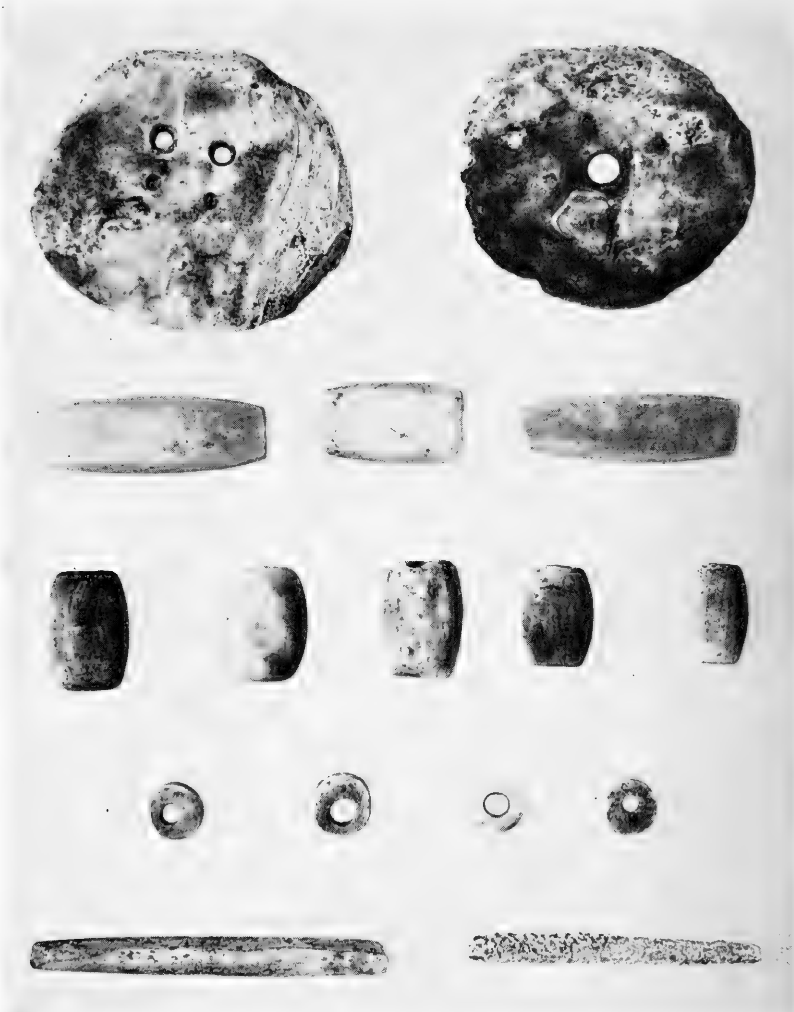


Fig. 67.—Shell beads and ornaments. Arikara.

pottery, ornaments, and implements do not serve as a safe means of distinction between the several tribes. Any differences which existed were nullified by the constant intercommunication and intermarriage between members of the neighboring villages. It is also doubtful whether much can be deduced from the arrangement of the lodges in the villages.

The physical type of the region is likewise quite uniform, with the result that the skeletal remains of the inhabitants themselves tell but little. The best means of distinguishing between the occupants of the various villages is in the manner of disposal of the dead. The Mandan, the Hidatsa, and the Cheyenne practised exposure of the dead on scaffolds with usually secondary burial of the bones. The Arikara and the Arapaho buried the dead directly.

Excavations in the four sites which were worked were carried on in the refuse mounds, cache pits, house rings, and cemeteries. An extensive archeological collection was made consisting of pottery, implements and ornaments of bone and stone, and a good many objects of European manufacture from the historic Arikara site. An interesting discovery was a number of glass beads, pendants, and other ornaments of native manufacture. This art, the origin of which is a mystery, was described as practised by the Mandan and Arikara by Lewis and Clark in 1804, but examples of it in collections have been extremely rare.

A large collection of skeletal material was made, representing 110 individuals, filling an important gap which has heretofore existed in the collection of the division of physical anthropology.

The region has by no means been exhausted, and a number of sites yet remain to be positively identified.

ARCHEOLOGICAL INVESTIGATIONS AT PUEBLO BONITO. NEW MEXICO

During the spring and summer months of 1923, Mr. Neil M. Judd, curator of American archeology, United States National Museum, continued his investigation of prehistoric Pueblo Bonito[1] under the auspices of the National Geographic Society. As heretofore, Mr. Judd's staff consisted of several trained assistants; 27 Navaho and Zuñi Indians were employed for the actual work of excavation.

During the explorations of 1921 and 1922, the expedition devoted its efforts primarily to excavating the eastern portion of Pueblo Bonito. In this area is to be found the finest type of prehistoric

[1] Smithsonian Misc. Coll., Vol. 72, Nos. 6 and 15; Vol. 74, No. 5.

FIG. 68.—At the close of the 1923 season a view of Pueblo Bonito from the north cliff of Chaco Canyon revealed the extent of the National Geographic Society's explorations. The size of this prehistoric village may be gauged by comparison with the five figures on the edge of the circular room in the middle of the picture. (Photograph by E. L. Wisherd. Courtesy of the National Geographic Society.)

masonry north of Mexico; it is that last erected at Pueblo Bonito and overlies the partially razed walls of other equally distinct types of construction. The secular rooms and the circular kivas, or ceremonial chambers, associated with them formed a group of structures occupied by one of the immigrant groups which added greatly to the original population of Pueblo Bonito and helped to spread the fame of this remarkable village throughout a large portion of ancient America. Excavations during the two years mentioned established the fact that this eastern portion of Pueblo Bonito, although comprising the largest and finest rooms in the entire village, was deserted at some time prior to final abandonment of the community.

The explorations of 1923 centered in the northern section of the ruin. Much of the expedition's efforts this year were devoted to removal of the vast accumulations of debris and blown sand which covered the fallen walls. It was in this particular section that the Hyde Exploring Expedition made its remarkable discoveries during the years 1896 to 1899. Conforming to a custom of the time, these early explorers threw the refuse from each room into that last excavated. Prehistoric habitations were not then regarded as objects of instruction in connection with the pre-history of our country and no concerted effort was made to support insecure walls, or to leave excavated ruins in a condition that would invite popular attention.

In removing the accumulations of earth and stone from the northern portion of Pueblo Bonito the National Geographic Society's Expedition of 1923 exposed three new kivas or ceremonial chambers and 26 previously uncharted and unexplored dwellings and storage rooms. A few of these structures had been destroyed by fire during or following the time of occupancy. In them and in other neighboring rooms a considerable collection of cultural material was recovered and has been forwarded to the United States National Museum.

In addition to the investigations pursued within the walls of Pueblo Bonito proper, search was made in the adjacent areas for further evidence of building operations. Enormous piles of blown sand and fallen masonry were removed from the outer east and northeast walls of the great ruin—débris which heretofore has completely concealed the first-story walls of the ruin. In removing this débris a veritable network of foundation walls was disclosed. These foundations connect directly with similar walls exposed beneath the floors of rooms excavated during 1921 and 1922; although obviously prepared as supports for heavy structures it is equally certain that these foundations were never utilized subsequent to their preparation. Plans for the con-

FIG. 69.—The roof of a Pueblo Bonito council chamber was a very complicated affair. Beginning on eight or ten low masonry supports, pairs of logs lay close to the kiva wall; above these were other poles laid in threes, fours, etc., until a neat vault, flat on top, covered the room. (Photograph by O. C. Havens. Courtesy of the National Geographic Society.)

FIG. 70.—Beneath a vast accumulation of earth, sand, and stone on the north and northeast sides of Pueblo Bonito were a number of foundation walls which had been prepared for contemplated additions to the village. Some of these walls are shown at the lower left. (Photograph by O. C. Havens. Courtesy of the National Geographic Society.)

struction of the later dwellings were altered and the Pueblo Bonito of to-day affords evidence of the extent of these alterations.

After the northern group of habitations had been examined, the east court was cleared of débris to a point corresponding with its last

FIG. 71.—Extensive repairs have been made to strengthen the shattered walls of prehistoric Pueblo Bonito and preserve its masonry for future generations. Four stories are evident in this particular view. (Photograph by Neil M. Judd. Courtesy of the National Geographic Society.)

level of occupancy. Earlier levels were disclosed beneath the latest one and the exploratory trenches also exposed the partially razed walls of several abandoned kivas. The depth of these now hidden structures furnishes abundant proof of the antiquity of Pueblo Bonito and the length of the period during which it was occupied.

Fig. 72.—This view of work in progress on the west side of Pueblo del Arroyo illustrates the extent to which fallen masonry and blown sand will accumulate. (Photograph by O. C. Havens. Courtesy of the National Geographic Society.)

Fig. 73.—The outer southwest corner of Pueblo del Arroyo during the course of excavation. In this section, nine rooms, previously unsuspected, were discovered. (Photograph by O. C. Havens. Courtesy of the National Geographic Society.)

As opportunity permitted during the exploration of Pueblo Bonito, attention was also directed to a neighboring ruin, Pueblo del Arroyo. Excavations in this latter village were under the immediate supervision of Mr. Judd's chief assistant, Mr. Karl Ruppert, of the University of Arizona State Museum.

This first season's exploration in Pueblo del Arroyo resulted in the complete excavation of one kiva and 20 living rooms. One of the latter is 58 feet long but its original length, before certain partitions were constructed, had been almost twice as great. In addition to the excavations within the walls of Pueblo del Arroyo itself an accumulation of débris was removed from the south and west sides of the ruin. In this débris nine small rooms were unexpectedly discovered—rooms which formed no part of the original ground plan of the pueblo.

Several unique specimens of pottery were recovered during the initial explorations in Pueblo del Arroyo and the success of this past season increases the belief that this particular ruin possesses much that will add to the scientific importance of current studies in Pueblo Bonito. Pueblo del Arroyo appears to have been designed and erected as a unit; it lacks the many intricate problems created by successive waves of immigration so evident in Pueblo Bonito. The 1923 explorations in Pueblo Bonito and Pueblo del Arroyo were conducted at a cost of more than $18,700. The success with which this expedition has been rewarded during the past three years warrants the belief that the National Geographic Society will continue its explorations during the next two years at an estimated cost of $15,000 annually. This is in conformity with the Society's program as adopted by its research committee in 1921.

EXPLORATIONS IN SAN JUAN COUNTY, UTAH

Bordering the Rio Colorado in Utah are vast areas which, owing chiefly to their inaccessibility and barrenness, have thus far escaped thorough examination by men of science. Certain portions of these areas, indeed, have never been visited by white men. To investigate one such district, that lying immediately east of the Colorado and north of the San Juan rivers, and to determine whether further, more detailed researches therein were desirable, the National Geographic Society, in cooperation with the Smithsonian Institution, organized a small reconnaissance party for explorations during the months of October and November; Mr. Neil M. Judd, curator of American Archeology, United States National Museum, was designated leader of this expedition.

Fortified with all the information obtainable, most of which was later found to be useless, Mr. Judd proceeded to Kayenta, Arizona, upon conclusion of his annual explorations for the Society in Pueblo Bonito. At Kayenta, the limit of automobile transportation, saddle and pack mules were obtained for the prospective journey. Besides Mr. Judd the party consisted of John Wetherill, guide, E. L. Wisherd, photographer for the National Geographic Society, George B. Martin of Denver and Julian Edmonson of McElmo, Colorado, assistants. Two Navaho Indians who professed to know something of the region to be visited failed, in turn, to appear as the time for departure approached.

It had been planned to swim the Rio San Juan at the mouth of Piute Canyon but the river, being still in flood, forced a long eastward detour that cost the expedition several days' time and brought it to the Clay Hill divide by way of Grand Gulch. Further delay was experienced at this point in recovering a quantity of grain and provisions which Indians had failed to deliver, on a previously designated date, at the Clay Hill Crossing.

Having gained the west slopes of the Clay Hills, seven of the 12 pack mules were pastured in a secluded cove at the head of Lake Canyon and those supplies actually required for the return journey were cached nearby. With fewer animals and equipment to care for and with only a week's rations, more rapid progress could be made and a proportionately larger area traversed in the limited time available for actual exploration.

From this base camp the party continued in a northwesterly direction to the Rio Colorado at Hall's Crossing, thence along the river edge into Moki Canyon. The latter, because of its name, had been chosen as one of the objectives of the expedition, under the belief that numerous remains of prehistoric habitations would be found in its deeper recesses.

Moki Canyon had been represented as about five miles long and enterable, on foot only, at its mouth and extreme head. Mr. Judd not only led his pack train into the narrow gorge, but he advanced with it 18 miles or about two-thirds the total length, over quicksands and rock ledges that added frequent barriers and not a little danger to the expedition.

Signs indicative of former Indian trails were noted at intervals throughout that portion of the canyon traversed and on one of these, after having directed the other members of the party to return to the Lake Canyon cache, Mr. Judd and his guide climbed the north wall of Moki Canyon in order to ascertain the location and characteristics of

FIG. 74.—The Clay Hills extend southward to the Rio San Juan as an unscalable barrier of red and gray shale, overtopped by sheer walls of pink sandstone. (Photograph by E. L. Wisherd. Courtesy of the National Geographic Society.)

FIG. 75.—When Moki Canyon cut its tortuous course, massive caves were formed at every angle and in these caves prehistoric peoples sought refuge from the elements and from their tribal enemies. (Photograph by E. L. Wisherd. Courtesy of the National Geographic Society.)

FIG. 76.—The expedition's pack train crossing the sandstone ridges that reach out from the base of Navaho Mountain, en route to the Rainbow Natural Bridge. (Photograph by E. L. Wisherd. Courtesy of the National Geographic Society.)

FIG. 77.—The Rainbow Natural Bridge, one of the most majestic and inspiring spectacles in the United States, rises to a height of 309 feet yet it is dwarfed by the sheer red walls of the canyon which shelters it. (Photograph by E. L. Wisherd. Courtesy of the National Geographic Society.)

what is more recently known as Knowles Canyon. They had with them at this time only their saddle animals and one pack mule, but to afford some understanding of the topography of the entire region traversed by the expedition it may be noted that, in leaving Moki Canyon, Messrs. Judd and Wetherill progressed only 15 miles in six hours' time and then, at dark, found themselves less than 2 miles from their last previous camp.

With the party reunited at its Lake Canyon cache the return trip to Kayenta was begun. Although handicapped by rain and dense fog

FIG. 78.—Thin fingers of pink and red sandstone tower above the yellow floor of Monument Valley pointing the height of the rock mesas that once covered northern Arizona. (Photograph by E. L. Wisherd. Courtesy of the National Geographic Society.)

which for three days almost obscured the dim Indian trail they were following, members of the expedition finally crossed the Rio San Juar immediately north of Navaho Mountain and thence visited the Rainbow Natural Bridge. Mr. Judd, as assistant to Dean Byron Cummings, was a member of the party which discovered this great stone arch on August 14, 1909.

The results of these recent explorations north of the Rio San Juan in Utah indicate the desirability of further, more extended archeological investigations; it is felt that the botanical and biological sciences would profit to a less degree. Animal and plant life in this region, according to Mr. Judd's observations, are neither plentiful nor greatly diversified, at least in the fall season. Such prehistoric habitations as were visited are small, crudely constructed affairs which suggest temporary occupation by small, migratory bands or family groups. Traces of a people older than the cliff-dwellers were observed in several localities; further research should afford a clearer conception of the cultural development of these two distinct types of cave folk and, at the same time, disclose their relationship to other prehistoric tribes of the great plateau country.

Several unavoidable factors, however, will tend to limit and restrict exploration of the uninhabited area north of the Rio San Juan. Water is at a premium except in the deeper canyons where seeps and intermittent streams may usually be found; " tanks," or natural reservoirs, do not occur on the broad sandy mesas separating the canyons. All supplies must be transported at least 200 miles by pack mules and quicksand in the narrow gorges is certain to prove troublesome except during the late fall and winter months.

ARCHEOLOGICAL FIELD-WORK IN NEW MEXICO

In May and June, 1923, Dr. J. Walter Fewkes, chief of the Bureau of American Ethnology, continued his field studies of ceramic decorations characteristic of the Mimbres Valley, New Mexico. The wonderful picture pottery of this region strikes the attention on account of the geographical position of the valley between Mexico and the pueblo region, and promises to shed light on prehistoric migrations of the southwestern Indians.

The Mimbres Valley is comparatively limited in extent and its pottery is being rapidly collected and sold as curiosities. In order to prevent the complete loss to science of this material and to give it a permanent home for future students, Dr. Fewkes obtained by purchase about a hundred specimens and added them to the collections of the National Museum. The designs on these are as a rule different from those already recorded. The Mimbres picture pottery (fig. 79) was made by a people that disappeared in prehistoric times without leaving a documentary trace of language or culture. Archeology is the only guide to its characterization. The pictures on these specimens are reproduced in Smithsonian Miscellaneous Collections, Vol. 76, No. 8, and in the present publication only a few general conclusions are considered.

Copper deposits in the Mimbres Mountains first attracted attention of the Spaniards to this area. Considerable quantities of this and other ores were mined here in early days by the Mexicans and shipped to Chihuahua; but the distance of the market and the interference of hostile Apaches rendered transportation rather hazardous. At the time of the survey of the boundary between Mexico and the United States, in 1854, the production of metal had practically ceased from the upper end of the Mimbres, which lower down was raided by hostiles and had become a dark and bloody ground. The Apaches were

Fig. 79.—Restoration of the parrot food bowl from the Mimbres Valley, New Mexico. (Painted by Mrs. George Mullett.)

embittered against the white people by atrocities they had suffered, and the toll of death of both races was large. From the year 1860 to 1864 considerable mining was done there by Americans, but the infamous killing of the Chief Mangas Colorado led to a general rising of all of the Indians seeking revenge, and for several years no white man entered or crossed this valley except with the greatest danger to his life. Hundreds of travelers were killed in Cook's Pass and the settlers in the valley were in continual danger. The Indians found in the Mimbres were known as Mimbreños Apaches. Shortly after the whites came into the neighborhood the town, Pinos Altos, became a center of mining industry, but existence there was precarious on account of hostile Indians who fought a battle within its limits. Little now remains of the old Santa Rita settlement. One of the bastions of this ancient fort is now used as the fuse house. The region of the old Santa Rita mine (fig. 80) has now changed so much that ancient landmarks are difficult to discover. The mountains over it are bare but not without interest. A standing rock called the Kneeling Nun, which rises to the east of the present copper company's building near the point of a high mountain, is said to commemorate an accident

FIG. 80.—Santa Rita Mine, New Mexico. (Photograph by Fewkes.)

in which a large number of miners lost their lives. This "Kneeling Nun" is supposed to be praying for the souls of the deceased men.

Whatever population existed in the Mimbres Valley in prehistoric times disappeared as a distinct people, probably having been absorbed into bands of Apaches, the so-called Mimbreños Apaches, now settled at San Carlos and other reservations.[1] It would be an interesting and important inquiry to study their legends in order, if possible, to determine any survival of the ancient people that may still exist. When Bartlett visited the valley in 1854 no villages of the original prehistoric population existed, although he speaks of ruins here and there and comments on fragments of pottery.

[1] The oldest inhabitants were probably the Mansos or Gorritas, so-called because they wore little caps, one of which is figured on a food bowl.

FIG. 81.—Design on the interior of a food bowl from the Mimbres Valley, New Mexico. U. S. National Museum.

FIG. 82.—Two specimens of Casas Grandes pottery found at Black Mountain ruin near Deming, New Mexico. U. S. National Museum.

It has been shown in former publications that the pottery (fig. 81) of the Mimbres resembles that of Casas Grandes in the adjoining State of Chihuahua, Mexico. There is no doubt that there was intercourse between the two peoples, for whole pieces of the brilliant

FIG. 83.—Food bowl with Gila Valley decoration found at Black Mountain ruin near Deming, New Mexico. U. S. National Museum.

Chihuahua pottery (fig. 82) were obtained in a ruin at Black Mountain, about six miles from Deming. In the same ruin there was found typical pottery from the Gila Valley (fig. 83), and the conclusion seems legitimate that this ruin was inhabited by an intrusive people contemporary with the ancient Mimbres settlements.

The so-called City of Rocks is situated near Faywood Hot Springs, which was cleared out some 15 years ago. The construction of the famous Hot Springs Hotel rendered it desirable to excavate the accumulated mud, and in removing it, a large number of votive offerings came to light. These consisted mainly of arrowheads, pipes, spear points, stone clubs, and various other objects. The spring was evidently a sacred shrine where offerings were thrown many years ago

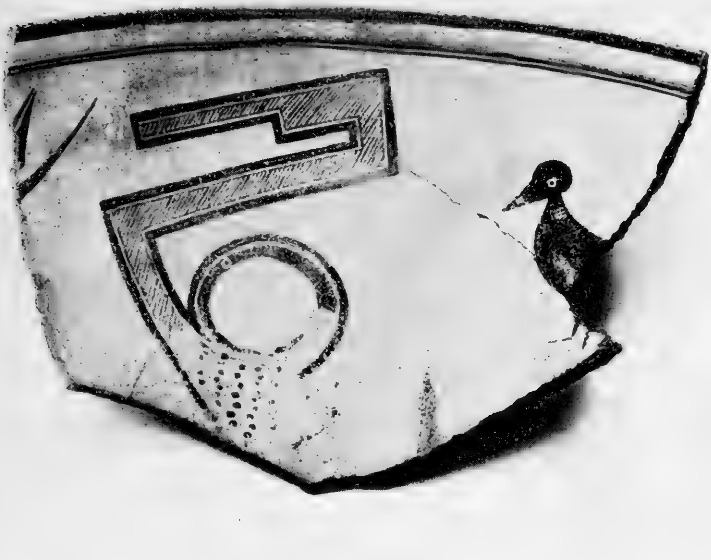


FIG. 84.—Fragment of ancient Zuñi pottery, Canyon del Muerto, Arizona, collected by Dr. W. H. Spinks. U. S. National Museum.

by the aborigines as sacrifices. Happily some of these specimens are now preserved in private hands; others are scattered through the valley. Among these objects are tubes called "cloud blowers," types of pipes that have been elsewhere described.

In May Dr. Fewkes visited Pinos Altos, on the divide separating the headwaters of the Gila and those of the Mimbres Valley. Near it is a large ruin situated on top of Montezuma Hill. This ruin, which from its position offers many problems for investigation, is one of the most important on account of the mixed character and decoration of the pottery. Its pottery may be decorated with designs from all the three ceramic areas here mentioned. In the high country north of Pinos Altos occurs the so-called Tularosa ware whose decoration connects pottery designs from the Mimbres with the pure pueblo. We must await more specimens from this region before we can determine the extent and meaning of the relation.

A beautiful fragment of ancient Zuñi ware (fig. 84) has been presented to the Bureau by Dr. W. H. Spinks, by whom it was found in a ruin in Canyon del Muerto. It bears a bird head and neck and the typical geometric design that occurs so frequently in modern Zuñi ware. In texture and color, however, this ancient example differs from

FIG. 85.—Boy Scouts watching progress of excavations, Weeden Mound, Florida.

the modern Zuñi and in these respects is more closely related to the brilliant yellow ware of Sikyatki, a well-known ruin of the Hopi. This is the first time that ceramic evidence has been adduced to show the relation of a Canyon del Muerto ruin to modern Zuñi.

ARCHEOLOGICAL FIELD-WORK IN FLORIDA

In November, 1923, the chief of the Bureau of American Ethnology made a preliminary trip to the southwestern coast of Florida. Although several archeologists, Cushing, Moore, Hrdlička, and others, have investigated this region, many unsolved problems are still awaiting solution, as known facts are too scanty for accurate generalizations. The archeology of this region has especial attractions to the chief of the Bureau on account of certain West Indian affinities of its prehistoric inhabitants. Through the kindness of Mr. E. M. Elliott, of St. Petersburg, he was able to make a short preliminary visit in anticipation of more intensive work which will naturally follow.

The prehistoric human inhabitants of the southern part of Florida were, from the nature of their environment, low in culture. Their

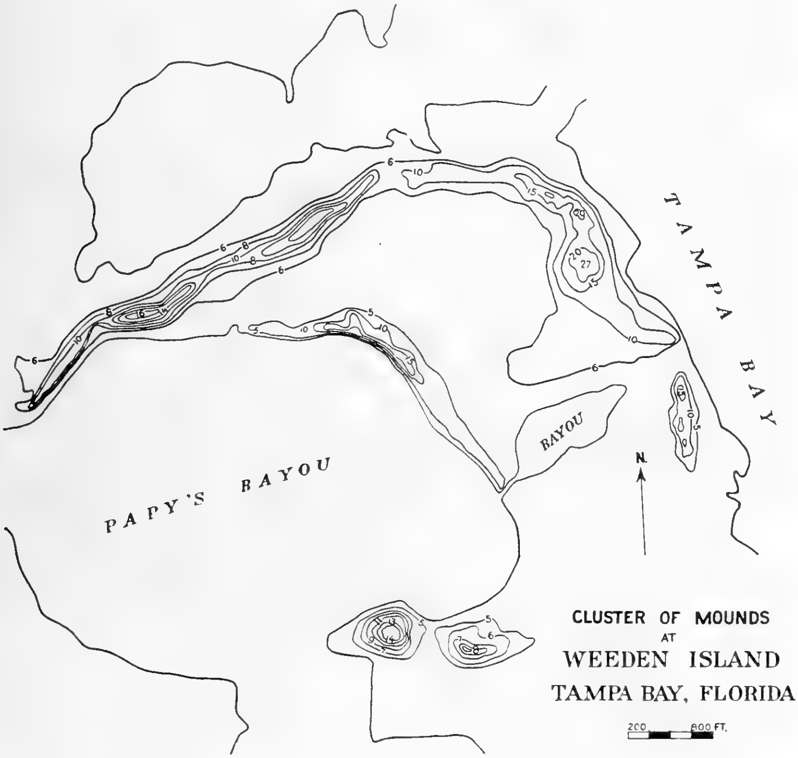


FIG. 86.

surroundings presented only scanty possibilities for a high development, and judging from data available not only was their material culture low, but they also owed little to outside influences. The visit was intended as a reconnaissance in which some of the numerous shell heaps and other remains of the culture antecedent to the coming of the white were inspected (figs. 85 and 86). The northern part of Florida has been well investigated but the Ten Thousand Islands are almost virgin soil for the archeologist. Caxambas, Key Marco, Horr's

FIG. 87.
A. Entrance of the canal to Shell Mound near Porpoise Point.
B. Landing place at Porpoise Point Settlement.
C. Mangrove jungle near canal at Porpoise Point Settlement.
D. Live oak on mound at Weeden's Island.
(Photographs by Fewkes.)

FIG. 88.
A. Typical shell-heap on Ten Thousand Islands, Florida.
B. Large tree on periphery of Weeden's Mound.
C. Inhabitants of Porpoise Point in front of their new schoolhouse.
D. Old house at Porpoise Point.
(Photographs by Fewkes.)

Island, Porpoise Point, Lostman's Key, and Choskoloski River have many little-known shell heaps. The keys near Caxambas appear to have been the center or the sites of a considerable population, judging from the number of these mounds.

This word with a different orthography, cacimbas, occurs in the Isle of Pines, Cuba, where 20 or 30 objects called Cacimbas de los Indios were examined by Dr. Fewkes several years ago. The word occurs on the mainland of South America and is interpreted as a " pipe." Cuban cacimbas are large vase-like objects buried in the earth and ample enough to contain a child. These vases are associated with low mounds showing effects of fire, and are supposed by some writers to be receptacles for turpentine or pitch with which the ancients pitched their canoes. Naturally it would be interesting to know why the name is applied to this region in Florida. Was the " Arawak Colony " in this neighborhood?

Several shell implements (fig. 92) were found at Horr's Island, near Caxambas, among which was a perforated circular disk of stone, called an anchor by the owner. It was smooth on one face and rough on the opposite, suggesting a quern or mill for grinding or bruising roots or corn, similar to those elsewhere described from Haiti and Porto Rico. The particular interest attached to this object which was one of many other specimens is that it is one of the few implements from the Ten Thousand Islands that substantiates the historical accounts that the Indians in southern Florida ground food into meal.

There are only a few modern settlements in the Ten Thousand Islands scattered along the southwestern coast of Florida, the most extensive of which, at Porpoise Point, consists of several houses and about 50 people, all related or belonging to one social unit or clan (fig. 88*c*, *d*). At this isolated community a school house has been erected for the natives by Mr. Elliott, and Mr. Little, who will serve as their school master, was carried to them on this trip. The oldest man of the settlement claims to be a Choctaw Indian; he is very old, and although there is some doubt of his ancestry, his descendants are mixed bloods. Life is very simple in this primitive place and the houses are mounted on piles like pile dwellings.

One of the most interesting clusters of shell heaps (fig. 88*a*) visited in Florida is situated near Porpoise Point. The shell heaps near this settlement are rarely visited or at least seldom described by archeologists, probably because it is hidden by a dense jungle of mangroves and approached by a narrow channel cut through this forest, and navigable only at half or full tide. The difficult entrance

Fig. 89.—Airplane view of pseudo-atolls near Weeden Island, Florida. (Photograph by Burgert Bros., Tampa, Florida.)

to this passageway is concealed as one approaches from the gulf, and appears to be artificial. The concealed entrance extends to a clearing in the forest, which is the site of the cluster of mounds on which now grow cocoanut palms, alligator pears, citrus fruits, bananas, and cultivated plants. The approach to one of the elevated shell heaps in this secret area is shown in the accompanying figure (fig. 87*a*). This area is the farm of the Porpoise Point settlement and would well repay archeological study. Several interesting shell implements were picked up on the surface and shallow excavations revealed a unique perforated bivalve fossil shell of unknown use. The whole collection thus far made is very large, and the work of Dr. Fewkes' assistant, Mr. M. W. Stirling of the U. S. National Museum, has attracted wide attention.

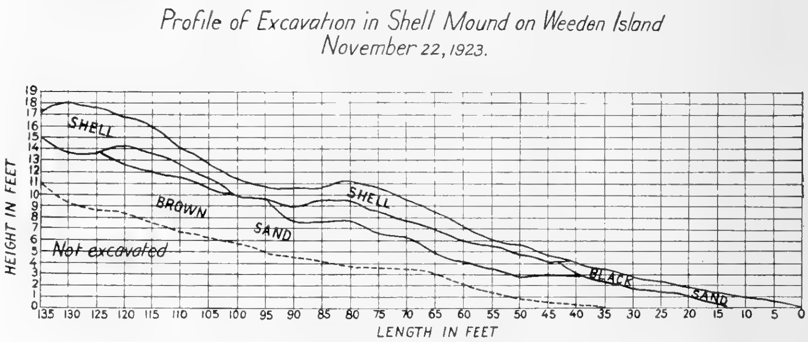


FIG. 90.

The site of Mr. Cushing's explorations at Marco was examined with great interest under the guidance of an old resident of Marco who remembered the valuable objects found there 28 years ago. The site is now much changed, the lagoon, from the muck of which so much was taken, is only a few hundred feet from the hotel; but the depression in which the most of the objects were found has been filled with shells leveled from nearby mounds in construction of a road, and the locality does not offer great inducements for future exploration.

Although it is hardly possible on such a slight acquaintance with Florida archeology to properly choose the most desirable sites for future work it would seem that the least known were those on the Ten Thousand Islands, especially from Caxambas southward. The Tampa Bay shell heaps, especially the cluster on Weeden's Island (fig. 91), about six miles from St. Petersburg, present many practical

FIG. 91.—Airplane photograph of shell-heaps on Weeden's Island, Tampa Bay, Florida. Weeden Mound shown in middle of the picture. (Photograph by Burgert Bros., Tampa, Florida.)

FIG. 92.—Shell objects from southwestern Florida.
A. Perforated fossil bivalve shell.
B. Shell pendant.
C. Unknown shell implement.
D. Shell gorget.
(U. S. National Museum.)

Fig. 93.—Frontal amulets from Mayaguez, Porto Rico, loaned to the U. S. National Museum by Mr. D. W. May.

Center, frontal amulet of shell.
Upper left, frontal amulet of indurated clay.
Upper right, frontal amulet of quartz.
Lower figures, frontal amulets of Falcore mineral.

advantages and a beginning was made on that island. A deep trench (fig. 90) was dug into the main mound in order to determine its character and stratification. It is believed to be a domiciliary mound or, since it is the largest in the cluster, that on which the chief's house was probably erected. Dr. Weeden's claim that De Soto and Narvaez landed on this mound seems probable, and if so we can identify it as the Calusa town, Ucita, which according to Bourne " stood near the beach, upon a very high mount made by hand for defense; at the other end of the town was a temple, on the roof of which perched a wooden fowl with gilded eyes."

The archeological problems of the southern part of Florida are complex and require more field-work than has yet been devoted to them. We have on the southwestern Florida keys many heaps of shell indicating several types, as eating places, domiciliary mounds, and

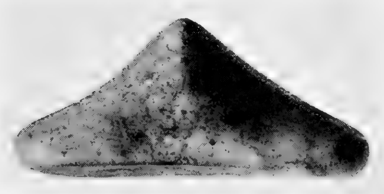


Fig. 94.—Three-pointed stone of the fourth type, Mayaguez, Porto Rico. Loaned to the U. S. National Museum by Mr. D. W. May.

Fig. 95.—Apical view of figure 94.

mounds of observation and defense. At the time of the discovery we learn from historical documents that a tribe of Indians called Calusa inhabited these keys and the names of certain towns of this tribe are recorded, but our knowledge of the ethnology, language and customs of the Calusa is scanty. Did the Calusa build the shell heaps or were they an intrusive people? Did the shell heap people come from the Antilles or were they Muskhogean? Archeology dealing with material culture can contribute to an answer to this question.

In the accompanying figure (fig. 93) are shown specimens of true Antillean amulets lately loaned to the United States National Museum by Mr. D. W. May, from Mayaguez on the west coast of Porto Rico. The central figure is a unique carved shell amulet with lateral wings different from any previously described. The other four amulets figured are likewise new. The three-pointed stone belongs to the fourth type, or that characterized by absence of head and legs but with a curved longitudinal depression on the base.

ETHNOLOGICAL STUDIES IN MAINE, CANADA, AND LABRADOR

Dr. Truman Michelson, ethnologist in the Bureau of American Ethnology, left Washington towards the close of May for a reconnaissance trip among the Algonquian tribes of northeastern United States and the adjacent parts of Canada including the Labrador peninsula. The Penobscot Indians of Maine remember their ethnology and folk-lore very well; but their language is dying. Practically none of the younger generation speak it; so it is only a matter of time before it is extinct. The native arts and industries are still kept up. In sharp contrast with them are the Malecites of "Indian Village," about 14 miles from Fredericton, New Brunswick, Canada. Everyone, even small children, speak the language; yet English is understood and spoken also. In their own homes, however, the Indian language is practically the only one in use. Their native arts and industries are still practiced. It was a rare treat to see them pound ash and then draw out the long splints which are used in basketry. The folk-lore is still remembered, but their ethnology properly speaking is nearly gone. It should be noted that as Penobscot, Malecite, and Micmac have a partially developed dual, in contrast to the Central Algonquian languages, it is plausible to consider this grammatical feature as due to Esquimauan influence.

Dr. Michelson left Sydney, Nova Scotia, June 19, and arrived at Port-aux-Basques, Newfoundland, the next day. From there he went to St. Johns by rail. While in St. Johns he took the cranial measurements of four Beothuk skulls in the local museum. These, of course, are too few in number to guide us regarding the racial affinities of the Beothuks, beyond their general American Indian one. Yet it may be worth noting that three of the skulls were mesocephalic (two nearly dolichocephalic) and one (a female) brachycephalic. It may be further noted that one skull (that of a male) had an unusually heavy supra-orbital ridge. Dr. Michelson left St. Johns on June 25 for Rigolet, Labrador, on the S. S. *Sagona*. The passage was rather severe for the season of the year, but this was more than recompensed for by the sight of so many ice-bergs. At Wesleyville the trip was livened by the ship striking rocks, fortunately without damage. It will be remembered that the *Portia* earlier in the season was fast on the rocks. And at Lord Arm, Dr. Michelson's steamer found the *Ranger* standing by *Seal,* whose propeller had been broken off by ice. The *Sagona* arrived at Rigolet, Labrador, July 3. The next day Dr. Michelson left in a motor boat for the Northwest River. The weather was rough and

FIG. 96.—Iceberg off the coast of Labrador. (Photograph by Michelson.)

FIG. 97.—Indians at the Northwest River, Labrador. (Photograph by Michelson.)

the first attempt was unsuccessful, but towards night-fall the weather moderated, and the Northwest River was reached early the next day. Dr. Michelson lodged at a Hudson Bay Company post during his stay at the Northwest River. The very best thanks are due to officials of the Hudson Bay Company at Rigolet and the Northwest River, as well as those of the Revillon Frères at the Northwest River, for their uniform courtesy and endeavor to make the expedition a success.

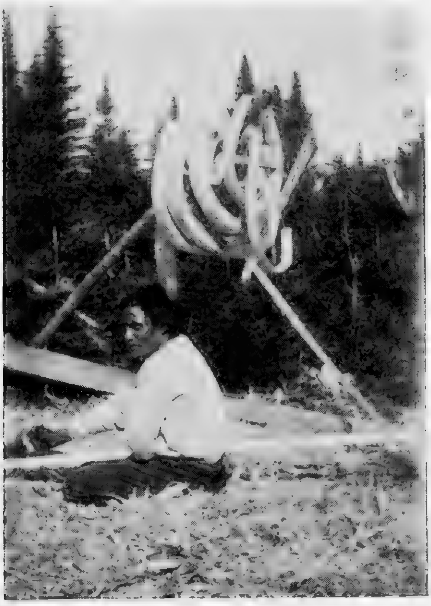


FIG. 98.—Indian making canoes at Northwest River, Labrador. (Photograph by Michelson.)

At the Northwest River there were some Indians from Davis Inlet, and at least one Nascapi from Ungava. Dr. Michelson took the physical measurements of a few, and made linguistic and ethnological notes. It follows that Nascapi is really not a distinct Algonquian language; it is the same as the Indian language spoken at Davis Inlet, and is merely a Montagnais dialect, differing only in a few details. From work done previously by others as well as by Dr. Michelson it is clear that the Indian languages at the Northwest River, Davis Inlet, and Ungava (*i. e.*, Nascapi) distinctly form a unit as opposed to the

Montagnais of Lake St. John, Mistassini, the "Cree" of Rupert's House, and the "Cree" of the East Main River. It should be mentioned that the folk-lore and mythology is much nearer that of the Central Algonquian than hitherto supposed. Dr. Michelson was informed that west of the Nascapi are some Indians whose language they cannot understand. Obviously these cannot be Eskimo or Montagnais; for the Nascapi know that the Eskimo and Montagnais differ but slightly from their own language. But who these Indians

FIG. 99.—Indian carrying a canoe at Northwest River, Labrador. (Photograph by Michelson.)

are is at present quite unknown. Later on Dr. Michelson was informed by William Cabot, Esq., of Boston, Mass., who has done a great deal of exploring in Labrador, that he had heard the same thing.

Dr. Michelson left the Northwest River July 21 for Rigolet and arrived there without adventure. He proceeded to Turnavik and from thence to St. Johns, Newfoundland. On the trip Dr. Michelson was able to take the physical measurements of a few Eskimos; up to that time he had taken only the measurements of a few mixed-blood Eskimos who are common on the Labrador coast and who constitute an important element of the so-called "Liveyeres." St. Johns was

FIG. 100.—Fox Indians, Tama, Iowa.
(Photograph by Michelson.)

FIG. 101.—Wigwam, Tama, Iowa. (Photograph by Michelson.)

reached on July 31, and on the same day Dr. Michelson left for Port-aux-Basques by rail. The train was wrecked at almost the center of the island, five cars leaving the track which was torn up for at least 50 yards and probably more. After a delay of more than 24 hours he reached Port-aux-Basques, taking the S. S. *Kyle* that night for North Sydney, Nova Scotia, which he reached early the next morning. From there he proceeded by rail to Tama, Iowa, to renew his researches among the Fox Indians. When not far from Chicago this train was also wrecked, but not badly. At Tama, Dr. Michelson finished a memoir on the Ceremonial Runners of the Fox Indians as far as practical in the field; he also gathered other ethnological data, and returned to Washington September 22.

ETHNOLOGY OF THE OSAGE INDIANS

Mr. Francis LaFlesche, of the Bureau of American Ethnology, spent a part of May and all of the month of June, 1923, among the Osage Indians. The purpose of the visit was to gather information relating to the fruits of plants, cultivated and uncultivated, which the Osage people learned to use for their sustenance before contact with the European races.

It was learned from Wa-no^{n}'-she-zhi^{n}-ga, better known as Fred Lookout, and his wife Mo^{n}'-ci-tse-xi (figs. 102, 103), and from other members of the tribe, that the Indian corn, or maize, which was known to many of the Indian tribes before the coming of the "whites," still forms a large part of the daily subsistence of the people, that they have over 20 different ways of preparing it for eating. As among other Indian tribes who cultivate the soil, the corn is a sacred food to the Osage, and it figures prominently in their ancient tribal rites and ceremonials. Green corn partly boiled or roasted on the cob, the grains removed from the cob and dried in the sun for use at all seasons, is liked much better by these Indians than the canned corn of the white man. Corn thus prepared for preservation is called, "u'-ho^{n}-ça-gi," and the woman who wishes to give a dinner to her friends never fails to have it on her table. A description of the Indian way of planting and cultivating the Indian corn was also given by Wa-no^{n}'-she-zhi^{n}-ga and his wife.

Many of the Osage Indians continue to use as food the roots of a number of wild plants, principally those of the *Nelumbo lutea*, commonly known as "water chinkapin" (fig. 105). The root of this plant, the native name of which is tse'-wa-the, has an important place

FIG. 102.—Mr. Fred Lookout, who gave information on plants used for food by Osage Indians.

FIG. 103.—Mrs. Lookout, who gave information on the various ways of cooking maize.

FIG. 104.—String of dried roots of *Nelumbo lutea* (water chinkapin) used for food.

among the food plants upon which the people depended for their daily sustenance. In recognition of the great value of this natural product of the soil, the ancient No$^{n\prime}$-ho^{n}-zhi^{n}-ga (learned men) made special mention of it as a sacred plant in the tribal rites which they formulated and transmitted to the successive generations.

The root of the water chinkapin was gathered in large quantities and dried for winter use. The outer skin was scraped away from the

FIG. 105.—View of the growing *Nelumbo lutea* (water chinkapin).

long armlike roots, which were then cut into one- or two-inch pieces, strung together (fig. 104) with thongs and hung up to dry in the sun on racks erected for the purpose. The root is eaten raw when fresh, and it is also cooked for immediate use. The nuts are also eaten when fresh and taste somewhat like chestnuts. The nuts are also dried and stored for winter use.

The çta-i$^{n\prime}$-ge (persimmon) is a fruit that is gathered in large quantities for winter use. In preparing the fruit for preservation the seeds are first separated from the pulp with a rude screen made of small saplings. The pulp of the fruit is then moulded into cakes, put on wooden paddles and held over live coals to bake. After baking the cakes are dried in the sun and stored. The persimmon cakes thus prepared resemble chocolate cakes. A specimen which was furnished by Mo^{n}'-çi-tse-xi is now in the National Museum. The process of preparing the persimmon for preservation is called Çta-i^{n}-ge ga-xe, making çta-i^{n}'-ge. In the autumn the people go out in groups and camp in the woods to gather persimmons for preserving.

Wa-to^{n}', the squash, was also cultivated by the Osage. They always raised a sufficient quantity to last till the next season. The pulp of the fruit, after removing the seeds and the skin, is cut into long strips which are hung up for a time to partly dry in the sun, after which they are taken down to be braided or woven into a mat-like shape and hung up for the final drying. When thoroughly dried these woven pieces are packed away in raw hide cases for winter use. The smaller pieces left over are strung together on strips of bark to be dried in the sun and stored. The squash was also counted as a sacred food and was given special mention in the ancient tribal rites.

A number of other wild plants afforded the Osage plenty of food, but the corn, squash, water chinkapin and persimmon are valued most because they never fail to yield a dependable supply of food.

ARCHEOLOGICAL WORK IN CALIFORNIA

During the past summer the Bureau of American Ethnology has been engaged in cooperative work in California with the Museum of the American Indian (Heye Foundation). At the request of Mr. Heye, Mr. John P. Harrington, ethnologist of the Bureau, was detailed to take charge of the exploration of the site of the principal rancheria of the Santa Barbara Indians, which is called the Burton Mound. Several years ago efforts were made to obtain permission to excavate this site, but when the Potter Hotel was erected on it in 1901 all hope was given up, and it was supposed that the opportunity for opening this mound had vanished; but this hotel was burned a few years ago, and the opportunity to excavate the site was obtained by Mr. Heye from the Ambassador Hotel Corporation. The excavations under the direction of Mr. Harrington for the Heye Museum and the Bureau of American Ethnology were begun early in May, 1923, and the first day's work located the position of the cemetery on the slope leading to the beach.

FIG. 106.—Collection of soapstone and sandstone bowls taken from Burton Mound cemetery. Left to right: G. W. Bayley, Professor D. B. Rogers, John P. Harrington. (Photograph arranged by J. P. Harrington.)

FIG. 107.—Santa Barbara beach, looking east from Castle Rock Bluff. The cove this side of the further wharf is the former puerto de cayucos or canoe landing place of the Indians in front of Burton Mound. (Photograph by J. P. Harrington.)

Several hundred human skeletons and a valuable collection of mortuary and other objects were found, among which was a fragment of a canoe made of soapstone, stone utensils and implements, mortars, pestles, beads, daggers, pottery, and other articles. By arrangement with the Heye Museum the report of this important discovery will be published by the Bureau of American Ethnology and a collection of duplicates of objects obtained will be deposited in the U. S. National Museum. The collection is the finest illustrating the culture of the Santa Barbara Indians that has been made in many years.

ARCHEOLOGICAL FIELD-WORK IN TENNESSEE

Mr. William Edward Myer, special archeologist, Bureau of American Ethnology, spent May and June, 1923, exploring the remains of a great prehistoric Indian town in Cheatham County, Tennessee. These remains are known as the Great Mound Group on account of the great central mound. Some interesting scientific problems were revealed by his excavations at this old town on the Harpeth River near Kingston Springs. Through the kindness of Mr. Wilbur Nelson, State Geologist of Tennessee, Mr. Crawford C. Anderson made a survey of the group. His maps are shown in figures 108 and 109. Through the efforts of Lieutenant Norman McEwen, of the 136th Air Squadron, Tennessee National Guard, aeroplane photographs were secured.

The remains of this ancient town or towns are found in two adjoining bends of the Harpeth, about a mile apart, and cover about 500 acres. The two sections of the town or two separate towns had each been protected by its own line of defenses, consisting in part of perpendicular bluffs and the remainder of palisaded walls.

GREAT MOUND DIVISION OF THE GROUP

In the upstream bend of the Great Mound division of the town he found a bold projecting hill which had been artificially shaped from base to summit. The original rounded summit had been leveled until a great plaza or public square, about 1,000 feet in length and 500 feet in breadth, had been formed. This plaza is indicated by *P* on figures 110 and 111. At the northeast corner of this plaza, at the brow of the tall terraced hill and overlooking the adjoining region for several miles, the Great Mound had been erected. It is denoted by *M* on figures 110 and 111. Along the eastern edge of this plaza two smaller mounds had been built. Three wide terraces had been formed along

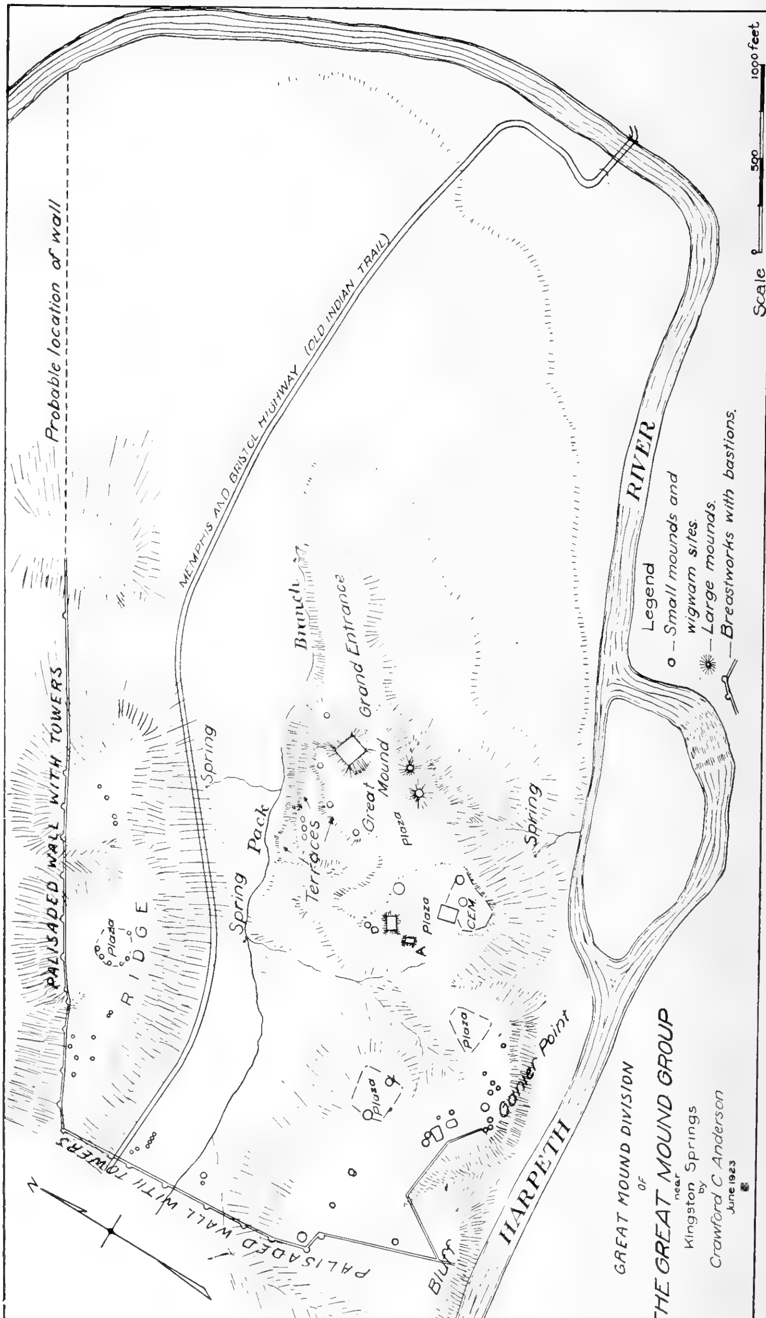

GREAT MOUND DIVISION
OF
THE GREAT MOUND GROUP
near
Kingston Springs
by
Crawford C Anderson
June 1923
Legend
o — Small mounds and wigwam sites.
— Large mounds.
— Breastworks with bastions.
Scale
0
500
1000 feet
Probable location of wall
PALISADED WALL WITH TOWERS
PALISADED WALL WITH TOWERS
MEMPHIS AND BRISTOL HIGHWAY (OLD INDIAN TRAIL)
RIDGE
Plaza
Spring
Spring
Pack
Branch
Grand Entrance
Great Mound
Terraces
Plaza
Plaza
CEM.
Spring
Plaza
Plaza
Garner Point
Bluff
HARPETH
RIVER
N

FIG. 108.

the northern side of this hill. Very faint traces of them can be seen at *T, T, T,* figure 111.

The Great Mound division of this ancient town was protected on the water side by the perpendicular cliffs of the Harpeth River. On the land side it was defended by an earthen embankment or breastworks surmounted by a wooden wall from which at intervals semicircular wooden towers projected. These earthen breastworks, which had formerly supported this wooden wall, were still to be found in the undisturbed woodlands where they yet extend about $1\frac{1}{4}$ miles, and there is evidence that they originally ran much farther. Wooden palisades, consisting of small tree-trunks, had been driven into the ground side by side and wedged together and the soil thrown against

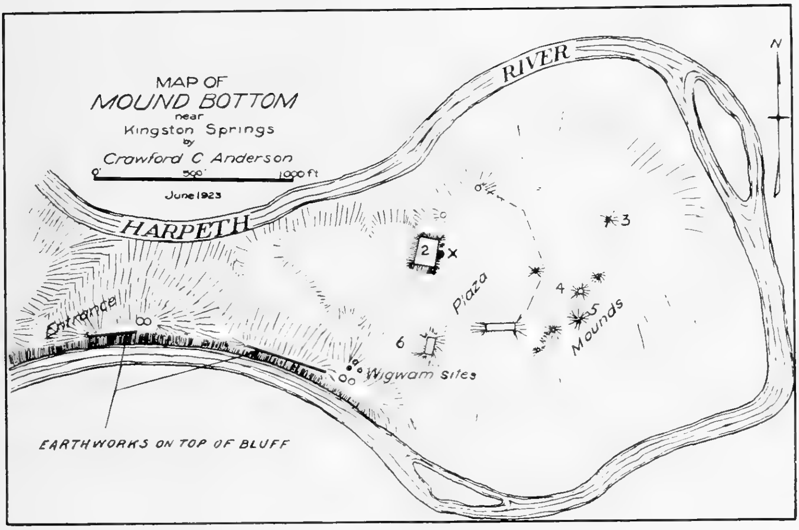


FIG. 109.

them until they were by this means firmly imbedded in these earthen embankments or breastworks. These palisades, bound closely together and strongly braced, formed a wooden wall which had been plastered on the outside in order to make scaling by an enemy difficult. Earthen bastions projecting beyond this line of wall at intervals of about 150 yards were still to be found. These had formerly supported semicircular wooden towers. The enemy advancing to attack was therefore subjected to fire from the defenders through port-holes along the main wall and also to a flanking fire from the warriors in the towers on these bastions. Faint traces of some of the timbers of these

Fig. 110.—Great Mound, in Great Mound Group.

palisades and wooden towers were found in the soil of these embankments.

This prehistoric town is notable for the artistic ability displayed by the ancient man who planned the beautiful, terraced, bold central hill with its fine plaza surmounted by towering Great Mound. No other remains of ancient man have been found in our southeastern

FIG. 111.—Aeroplane view of northern side of central hill, showing Great Mound, M, Plaza, P, faint traces of terraces at T, T, T. (Photograph by Lieut. Norman McEwen.)

United States which approach this Great Mound Group in an artistic sense. On the other hand, the pottery and the stone artifacts are somewhat ruder than those of the adjoining region. The remains of about 15 mounds of various sizes were found on this site.

While this great central mound topping the bold terraced hill formed the most striking feature of this ancient town, there were within the walls four other eminences whose summits had likewise been leveled into plazas. All these plazas yielded traces of earth lodges and other evidences of former buildings. On the edges of the terraces were the earth lodges of the common people. See map, figure 108. The larger mounds had probably supported important public buildings and the lodges of leading personages.

All the buildings unearthed appeared to have been destroyed by fire. A line of wall-post holes and fragments of the charred poles used for wall posts in the large building, *A*, can be seen in figure 112.

Under the fallen-in walls of this building the charred remains of woven cane-matting wall- hangings were found and carefully preserved. The woven design could still be discerned.

FIG. 112.—Wall post holes and fragments of charred wall posts of building A, Great Mound Group.

There is some evidence that this group of important buildings around five separate plazas and in different parts of the town very probably indicates that the population was made up of what had once been four or five separate groups of kindred peoples. These groups had probably formerly been autonomous. Here in their later home each group had gathered around their own public square in their own section of the town and thus preserved at least some of their old ceremonials and held together in some fashion their old organizations.

It is impossible to determine even approximately the number of inhabitants, but the large number of the buildings and the long extent of the walls to be manned required a population of several thousand.

MOUND BOTTOM DIVISION OF GREAT MOUND GROUP

Figure 109 shows a map of the Mound Bottom division of the Great Mound Group. This portion of the remains covers nearly all of the lower river bend which is called Mound Bottom by the local people. The accounts of the early white visitors to the region indicate that a line of walls with towers every 40 paces at one time extended around the edge of this river bottom. If so, all trace has disappeared under long cultivation. A curious line of earthen embankments was found on the narrow neck of bluffs through which entrance was gained to the ancient town. These embankments do not appear to have been portions of fortifications.

A photograph of a portion of Mound Bottom is shown in figure 113. Numbers 2, 4, 5, and 6 are large mounds. Number 1 is a wide artificial

FIG. 113.—Mound Bottom. Harpeth River, two miles below mouth of Dog Creek, Cheatham Co., Tennessee.

earthen platform adjoining mound number 2. Number 7 is a cemetery containing stone-slab graves.

It is not as yet possible to determine the age of these remains. Beyond all question the town had been destroyed long before the coming of the whites. In like manner the Indians living in this section when the whites arrived stated their ancestors had also found these vestiges of some unknown people lying silent and deserted along this beautiful river when they came into this region.

DENNY MOUND

Later in the summer of 1923 Mr. Myer explored a small mound on the Denny farm at Goodlettsville, Sumner County, Tennessee, which proved to be of unusual importance, in that it yielded relics which showed it to belong to a culture quite different from that of much of the surrounding region in the valley of the Cumberland in middle Tennessee.

Several of the potsherds found in this mound were decorated with fabric impressions which throw new light on the clothing of some of the southern mound-builder women and reveal important differences between some of the customs of the builders of the Denny mound and those of ancient man in the adjoining states.

The burial customs, pottery fragments, pipes, implements of bone and antler, copper ornaments, and other artifacts brought to light in this excavation were of great interest as they furnished intertwining clues which led to tracing out a cultural relationship between many widely scattered important ancient sites occupied by prehistoric man in the upper valleys of the Tennessee River in eastern Tennessee, northwestern North Carolina, the Shenandoah Valley, the upper valleys of the Potomac, the valleys of the New and the Kanawha, the central and lower Scioto valley, a site in the suburbs of Cincinnati, certain sites in the southern peninsula of Michigan, and in southern Wisconsin and elsewhere in our central northern states.

Probably the most interesting contributions to knowledge brought to light by the exploration of the Denny mound were the clues which led to determining what modern Indians are the descendants of the ancient mound-builders who erected this old Tennessee mound. A study of the material cultures aided by the scanty written records and traditions regarding the localities where cultures have been found somewhat similar to that of the Denny mound brings out the fact that the little outlying settlement of ancient people who lived at the Denny mound belonged to a culture group whose remains are found at various points in eastern Tennessee, northwestern North Carolina, southwestern Virginia, Shenandoah Valley, the upper Potomac valleys, the valley of the Kanawha, southern and central Ohio, southern Wisconsin, the southern peninsula of Michigan, and possibly in other sections. This culture group appears to have belonged to the Algonquian stock. The many interlocking evidences render it probable that the Denny mound and some of the other culturally related sites here mentioned were at some time occupied by the Shawnees or people closely akin to them.

REMAINS IN LINCOLN AND MOORE COUNTIES, TENNESSEE

Mr. Myer also visited Lincoln and Moore Counties, in the southern part of Tennessee, where he studied several ancient sites and surveyed and mapped a large and hitherto undescribed mound group on Elk

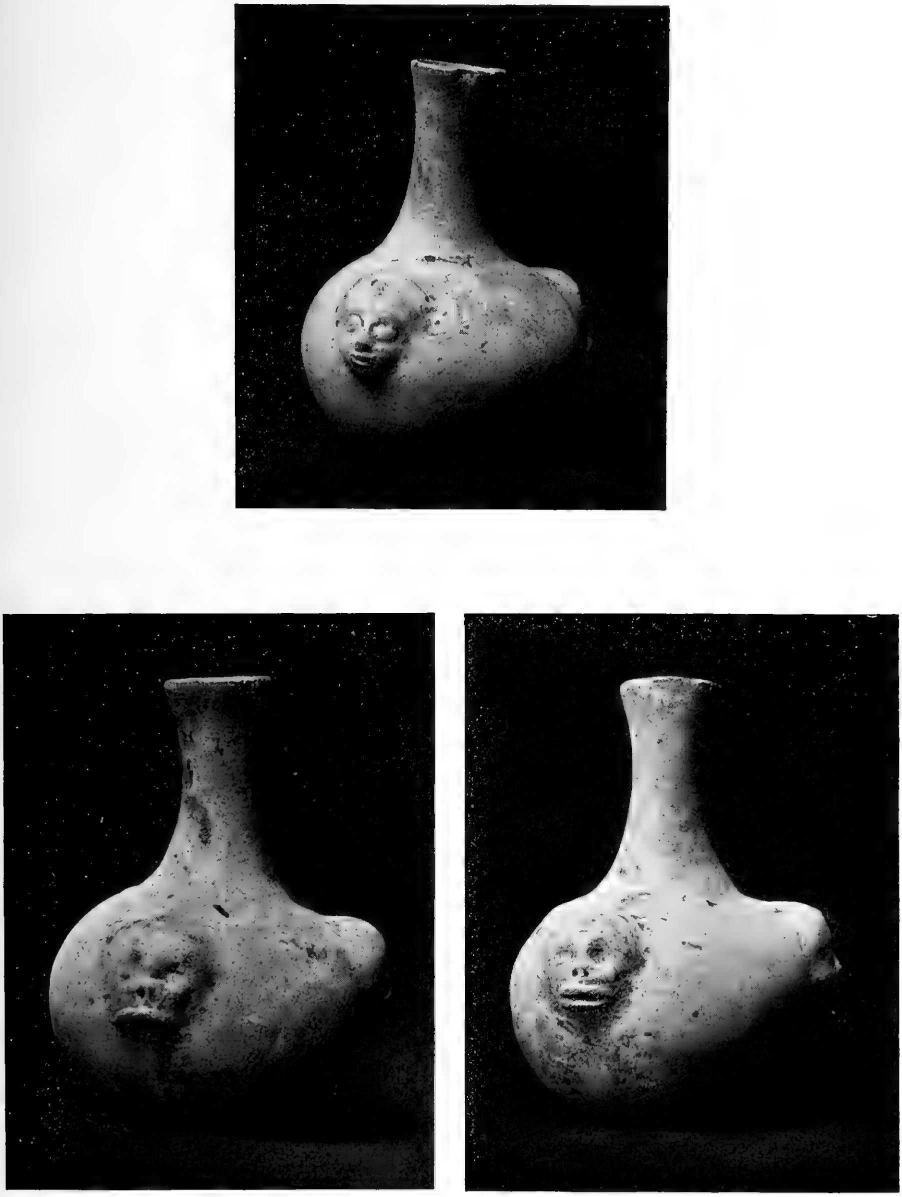


FIG. 114.—Vase from Lincoln County, Tennessee.

River, in the southern corner of Moore County at the point where Moore, Lincoln, and Franklin counties corner. This group of large mounds, plazas, and traces of ancient wigwam sites covers a large bottom on Elk River. Its accompanying cemetery is found on a tall bluff overlooking the site. These remains of some important ancient mound-builder town have never been explored. It has been named the R. H. Gray group in recognition of Mr. R. H. Gray's services to archeology in seeking out and accurately recording for the Bureau of American Ethnology 74 ancient Indian sites in Lincoln County where formerly only two had been reported. Through the kindness of Mr. E. C. Brossard, of Fayetteville, some unusual relics were secured from an ancient site in Lincoln County, on Swan Creek near its junction with Elk River. One of these, a long-necked vase decorated with three unique heads, is shown in figure 114.

FIG. 115.—Boat-shaped object from Lincoln County, Tennessee.

An exact duplicate of this vase in material, size, shape, and heads was found in the suburbs of Nashville, Tennessee, several years since. These very striking heads probably are connected with some ancient tradition or religious rite of these prehistoric men in Tennessee.

A fine boat-shaped object from the same Swan Creek site is shown in figure 115.

LINK GROUP

Mr. Myer also visited Humphreys County, Tennessee, and studied and mapped the Link group of mounds on Duck River, some six miles southwest of Waverly. This is the site where the famous cache of fine, long, chipped flint ceremonial blades and chipped flint implements now in the Missouri Historical Society collection was found. He secured some new information in regard to this important group and the surrounding region.

FIELD STUDIES OF INDIAN MUSIC

In July, 1923, Miss Frances Densmore went to Neah Bay, Washington, to continue her study of Indian music for the Bureau of American Ethnology. The purpose of the trip was to record the songs of Pacific Coast Indians for comparison with the songs of desert and plains tribes. The Makah were selected for this comparison as they are particularly efficient in the catching of whale and seal. The result fully justified the undertaking. Proof of the effect of environment and occupation on Indian song was obtained, together with descriptions of musical customs not found in tribes previously studied. The

Fig. 116.—Neah Bay village, Olympic Mts. in distance. (Photograph by Miss Densmore.)

resultant material comprised phonographic records of 103 songs, more than 200 pages of manuscript notes, 26 specimens of plants with descriptions of their use, 5 portraits of singers and numerous photographs of the locality. A considerable number of specimens relating to the material were obtained, and several specimens which the owners refused to sell were photographed with their permission.

Neah Bay is on the Strait of Juan de Fuca and lies within a few miles of the end of Cape Flattery. Across the Strait can be seen the mountains of Vancouver Island while back of the village rise the Olympic mountains (fig. 116). Communication between Neah Bay and the outer world is entirely by water. Long ago, the Spaniards came here, built a dock and "surveyed the place." An informant said this took place in the time of his grandfather's grandfather. The Indians were friendly to the Spaniards until they molested the women, when they drove them away. A trace of Spanish influence was found in the statement that the earth revolves once every day, but the Makah added that "the earth is a flat disk, supported by something underneath but resting on the surface of the water." One edge was said to be a little lower than the other, so that in revolving it dips below the water, this causing high and low tides. Further evidence of Spanish influence lay in the description of an armor made of narrow wooden slats, worn in war by the early Makah. The next white visitors were "Boston men" concerning whom it was said "they dug large deep holes and buried a great many bottles to prove they discovered Neah Bay."

Four tribes of Indians are under Neah Bay Agency, the largest number being the Makah who comprise 414 persons. They frequently exchange visits with the Indians on Vancouver Island but did not mention the tribes living on Puget Sound. A clear distinction was made between Makah songs and those of the British Columbia Indians; it was said, however, that many of the Makah songs had "B. C. words." No explanation was given for this usage. The words of the gaming songs were in the "Chinook jargon." Many songs were in a "dream language."

As an outstanding peculiarity of Makah music we note the custom of pounding on planks instead of drums. Timber was easily obtained and the material for a drum head could be obtained only by hunting in the mountains. The planks were "shag," made by splitting a log with a wedge, and the short sticks used for pounding were of the same crude manufacture. The Thunderbird dance was performed on the flat roof of a house and as an accompaniment for that dance a plank was placed on the ground near each side of the house, the company sitting beside these planks, facing the house, and pounding as they sang. A somewhat similar arrangement was used at a social gathering on the beach, attended by the writer (fig. 117). The planks are raised a few inches above the ground, giving space for resonance. Drums appear to have been used by individuals. Mrs. Long Tom (fig. 118) declined to sell her drum, saying "it was so much company for her in the long winter evenings." Certain songs were accompanied only by handclapping, and certain dances had no songs, being accompanied only by pounding on the planks.

Throughout the general culture of the Makah is seen the influence of the "caste system" and the keeping of slaves. Many acts were permitted only to the "first families" and forbidden to the "lower classes." In former times a prominent Makah owned at least 12 slaves usually obtained from other tribes in exchange for the various products that resulted from his successful whaling. These products included whale meat, oil, blubber, and bone. The possession of slaves affected the position of women, as they were relieved of much arduous labor. This enabled them to spend more time on their personal appearance and to enter more fully into an enjoyment of their children. A

FIG. 117.—Makah singing on beach. Pacific Ocean in distance. (Photograph by Miss Densmore.)

woman who was careful of her appearance washed her hair and massaged her face and body every day. Men as well as women rubbed their bodies with cedar bark fiber or with fine hemlock branches, the men following this with prayers for physical strength. Occasionally the women also desired great strength.

Two ideals were noted in this tribe, personal beauty in the women and physical strength in the men, and we find also a certain grace in social intercourse. For instance, each person at a feast was expected to sing a "gratitude song" before his or her departure and there were many songs, sung at social gatherings, in which men and women expressed an admiration for each other. A charming custom was that of "lullaby singing" by the older women which was always followed

FIG. 118.—Mrs. Long Tom. (Photograph by Miss Densmore.)

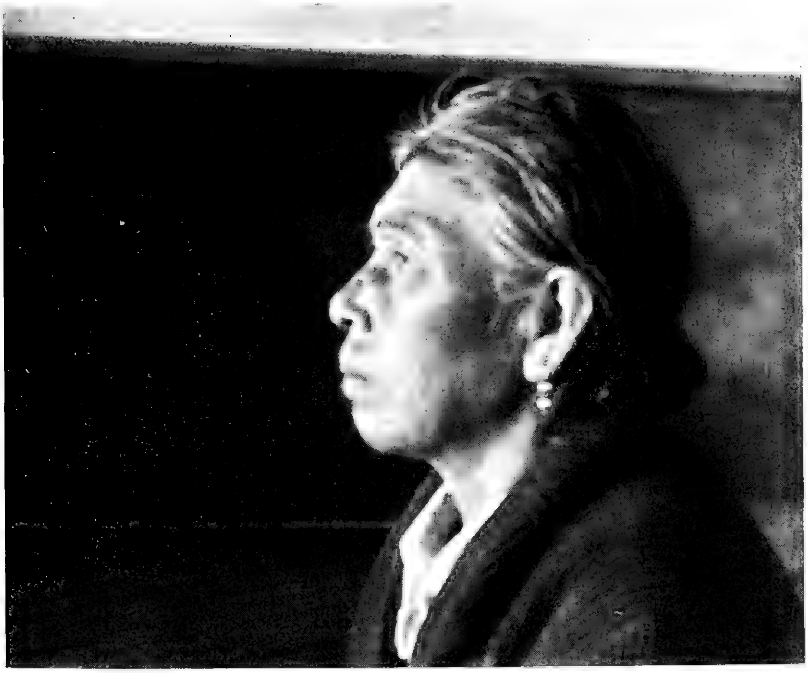


FIG. 119.—Mrs. Wilson Parker. (Photograph by Miss Densmore.)

FIG. 120.—Mrs. Sarah Guy. (Photograph by Miss Densmore.)

by gifts supposed to be bestowed by the infant. There were songs for boys and for girls. Frequently the words were supposed to be those of the child. Thus a lullaby for a baby girl contains the words

> "The only reason I cannot gather more berries
> Is that so many other babies are bothering me."

The following lullaby is addressed to a boy,

> "What a nice basket full of snipes you are carrying.
> You got them at Tcatcatiks."

The singer of this song would expect to be rewarded with a feast of snipes. Several of the lullabies were recorded by Mrs. Wilson Parker (fig. 119), whose head shows a deformation observed frequently among the Makah.

The wedding customs were elaborate, including mock and genuine feats of strength as well as dramatic performances of various sorts. An instance of the latter was the presentation of what might be termed a "model" of an island, given by a man to the girl who married his son. A song concerning this action was recorded by Mrs. Sarah Guy (fig. 120) and contains these words,

> "My island home is ready,
> There are many ducks around it."

The most characteristic songs and legends of the Makah are those connected with whale catching. In these songs we find tones prolonged to the length of four or more counts in slow tempo, suggesting the "*ahoy*," or call across the water, which is used among sea-faring people of other races. In addition to these very long tones the whaling songs contain short rhythmic units, crisp and decided, like the motion of the paddles in the water. The intervals and compass of these melodies is rather small. Mr. James Guy (fig. 121), who recorded whaling songs, said they were sung "in time with the paddles" and that between renditions the men held their paddles upright and gave a long wail or moan, imitating the sound made by a wounded whale

The prominence, power and wealth of a Makah depended on his success in catching whales. One or two whales was the average catch for a man in a season but sometimes a man caught four or five. In that event he was able to give an oil potlatch, at which about 500 gallons of whale oil were given away. Not only was the oil taken home by the guests but buckets of it were poured over the women relatives of the host who danced at the potlatch. The host even showed his lavish intention by pouring a large quantity of oil on the fire. In the songs of the oil potlatch a captured whale is supposed to be speaking.

FIG. 121.—Mr. James Guy. (Photograph by Miss Densmore.)

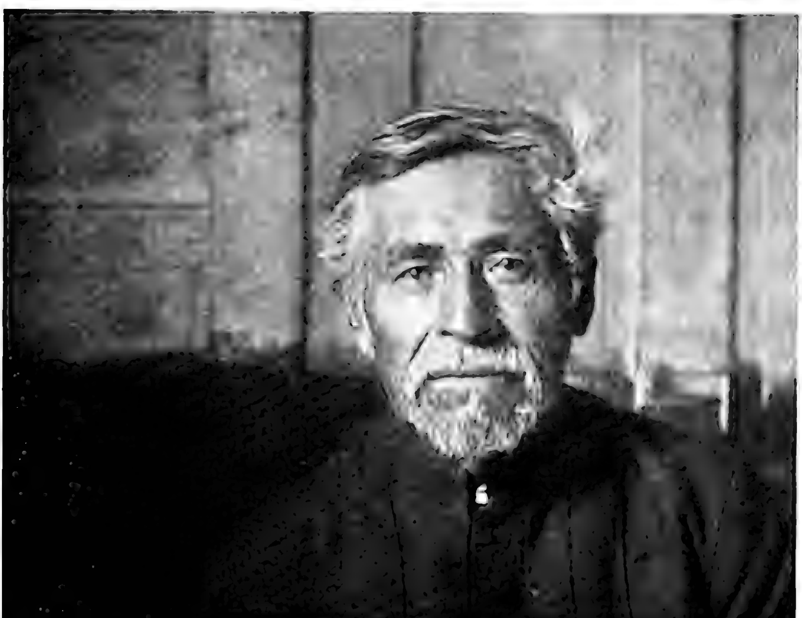


FIG. 122.—Young Doctor. (Photograph by Miss Densmore.)

Among the songs peculiar to this tribe was one learned from the frogs, another concerning the story of an encounter between a man and a shark, and another concerning a mysterious creature of the sea called by a term meaning " lightning belt of the thunderbird." Concerning one song it was said, " In old times the people believed that the singing of this song would bring rain." Three " echo songs," with prolonged tones, were recorded by Young Doctor (fig. 122) who said he heard them in a dream, sung by men in a canoe on a very calm day. Young Doctor was an excellent singer, a proficient, industrious worker in wood and whale bone and formerly treated the sick, using a rattle of shells strung on thin whale bone.

Other subjects studied were war, contests of strength, and the ordinary potlatch, with its songs of invitation, welcome and feasting.

The following incident is of interest, in connection with the study of Indian music. Miss Densmore played for Young Doctor the phonograph record of a Yuma song. He listened attentively and then said, " That sounds like a song calling on the southwest wind and asking for rain. It is calling for a soft wind, not a strong wind." He was interested to learn that the song came from a desert country where the desire for rain is often in the minds of the people, and the song belonged to the Kurok, or Memorial ceremony of the Yuma. The words of this song were in an obsolete language, unknown to the man who recorded it.

Two phases of singing by the Makah women deserve special mention. It was said to be the custom with all old songs that a man sang the introduction, then a certain woman pronounced the words, after which all sang the song. This woman acted as a sort of precentor, and her action was not unlike that of " lining out the words." The second interesting phase of singing by the women was the use of a high drone, or sustained tone, while the other singers gave the melody. It was said " the Makah women sometimes do this if they are not sure of a song and are asked to help with the singing, but the Quileute women do it a great deal, calling it the ' metal pitch ' because it is like a piece of metal which can give only one pitch." Miss Densmore heard and noted this high drone in the singing of Papago women in southern Arizona, where it seemed to be regarded as an ornamentation to the music. A high drone is said to characterize the singing in " some parts of European Russia and all over the eastern Caucasus, in the wild recesses of the mountains where the native music has not felt the modifying influence of European culture." Its presence in these localities in the United States, and not in tribes living farther from the Pacific coast, is of peculiar interest. There has been no opportunity for investigating the possible use of the high drone by California tribes.

After leaving Neah Bay Miss Densmore went to Prince Rupert, B. C., where she interviewed some members of the Tsimshian tribe and learned that their old songs are remembered by at least one member of the tribe. No attempt was made to record songs in British Columbia, but there seems an important opportunity for musical work in that region.

FIG. 123.—Unfinished banner stones, showing different stages of workmanship on various types found in eastern Pennsylvania.

BANNERSTONE INVESTIGATIONS IN PENNSYLVANIA

John L. Baer, special archeologist for the Bureau of American Ethnology, spent three months in eastern Pennsylvania studying bannerstones and the method of their manufacture. Four more aboriginal workshops, where bannerstones were made, were located; two along the Susquehanna and two along the Delaware. None of these, however, was as large as the one formerly reported on Mt. Johnson Island in the Susquehanna River. At each of these workshops the bannerstones were made either after different patterns or of a different material. By learning the sources of the various types of these ceremonial objects Mr. Baer hopes to discover some of the prehistoric migrations of certain tribes of the American Indians. Many interesting specimens of bannerstones were located in small private collections in Pennsylvania. In one town there are nearly a dozen which were found within a radius of 10 miles. Unless this section of the country was specially favored, bannerstones must have been much more numerous than has heretofore been supposed.

Numerous reports of a cache of rhyolite blades, ranging from 20 to 150 per cache, attracted Mr. Baer's attention to the source of material in the South Mountains west of Gettysburg, Pennsylvania. These prehistoric rhyolite quarries were discovered and described by Prof. W. H. Holmes a number of years ago. Recently a trench for a pipe-line was dug over the side of the mountain, which exposed chips and reject blades of rhyolite and trap hammers for a distance of half a mile. The bushels of rejects scattered along this narrow path are indications of the magnitude of this prehistoric workshop, which was as broad as it was long.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 76, NUMBER 11

THE FRESHFIELD GLACIER, CANADIAN ROCKIES

(With 9 Plates)

BY
HOWARD PALMER

(Publication 2757)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
AUGUST 2, 1924

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

THE FRESHFIELD GLACIER, CANADIAN ROCKIES[1]

By HOWARD PALMER

(With 9 Plates)

To the student of the phenomena of active glaciers the Canadian Rockies offer an advantageous and almost untouched field. Three of the most accessible ice tongues along the Canadian Pacific Railway have been made the subject of detailed investigation, but on the remoter and larger ice systems almost no work has yet been done. During recent years, the Alberta-British Columbia Boundary Survey has produced a series of admirable contour maps (scale 1 : 62500) which delineate the continental divide, together with its adjacent mountains and glaciers. Thus there is now available to the glacialist an excellent groundwork for the prosecution of his particular researches.

Of the newly mapped glaciers, the Freshfield is the most attractive. Size, ease of access, and majesty of scenery all commend it. Lying in a direct line 40 miles northwest of Lake Louise, five days of comfortable traveling will take one to its tongue. The trail distance is about 65 miles, all the way through wild mountain valleys with peaks, glaciers, torrents and lakes in plenty to beguile the march. A good camp ground is to be had not far from the tongue and there is ample feed for the horses.

The Freshfield massif is a well-defined group of peaks about 12 miles square situated in a semicircular loop of the continental divide between tributaries of the North Saskatchewan and Columbia rivers. Its drainage is principally to the former. It is separated from the Yoho-Waputik group on the southeast by Howse Pass (5,010 feet) of historic fame, and from the Forbes-Lyell group on the north by Bush Pass (7,860 feet). There are 25 peaks in the group surpassing 10,000 feet in elevation, Mt. Barnard (10,955 feet) being the loftiest. Eleven of them exceed 10,500 feet.

The Freshfield glacier and tributaries occupy an elliptical basin in the midst of the group, nine miles long from southeast to northwest, and four miles wide. Around the periphery the peaks stand in

[1] A summary of glacier measurements and observations in the Canadian Alps, with references, will be found at the end of this paper, page 13.

line, forming a retaining wall which almost completely incloses it. The ice discharges through a gorge-like valley to the northeast in a single tongue three-quarters of a mile wide and three miles long, buttressed on both sides by mountain masses over 10,000 feet high. Excepting this valley, there is no real break below 9,000 feet in the entire sweep of the rim. The area of the ice and névé in the Freshfield system proper is approximately 22 square miles, but adjacent connected, or nearly connected, glaciers on the outer slopes of the basin bring the total area of ice in the group up to about 40 square miles. The trunk glacier from its most distant source to the tongue is almost exactly nine miles long.

In the summer of 1922, the writer in company with Dr. J. Monroe Thorington and Edward Feuz, Swiss guide, visited the Freshfield group mainly for the purpose of ascending some of the unclimbed peaks. At the same time, however, it was felt that advantage should be taken of the opportunity to make such observations on the glacier itself as conditions might permit. Accordingly the writer brought along a small light telescopic level reading to 5′ of arc on both vertical and horizontal circles, a prismatic compass, a clinometer, a 100-foot steel tape for base-line measurements, white paint for marking stations, white cotton cloth and wire for erecting signals, etc., in addition to the usual aneroids and thermometers employed in mountaineering. As it turned out, we were able to spend only eleven days at the glacier, and of these only three were exclusively devoted to observations on it, so that the results presented herewith cannot claim to be more than of a preliminary and tentative nature. We did, however, familiarize ourselves with nearly every part, for in the course of our five ascents (Mts. Gilgit, Nanga Parbat, Trutch, Barnard, and Freshfield) we travelled, on the ice itself, some forty miles besides obtaining excellent views from the summits.

The work attempted falls under the following headings: (1) measurement of the rate of surface velocity of the ice; (2) instrumental triangulation for the location and measurement of a line of stones and for effecting connection with the government map; (3) observations on the tongue and its retreat; (4) observations on general features of the glacier.

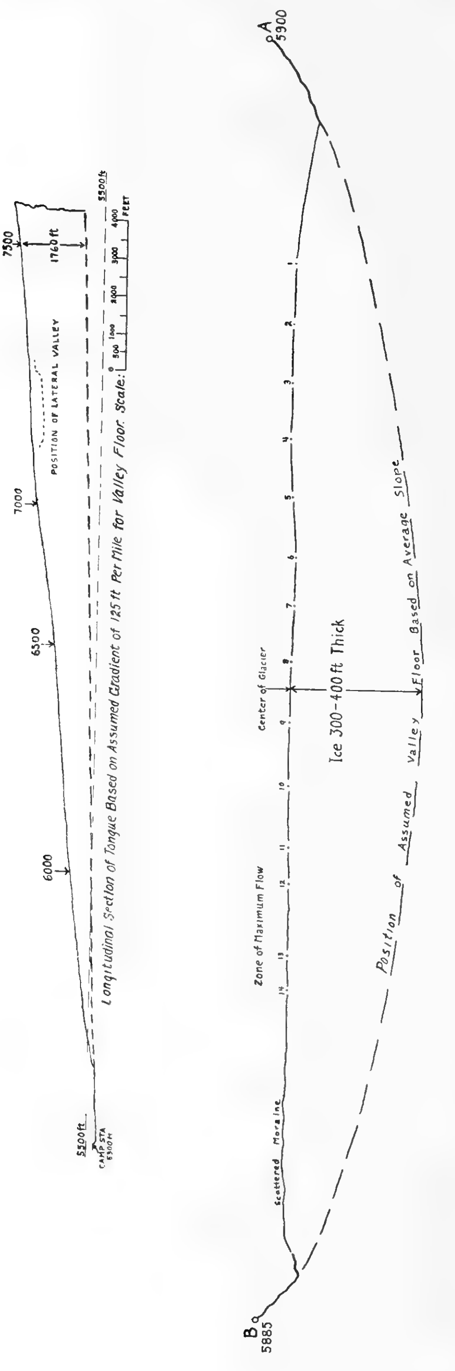
1. MEASUREMENT OF THE RATE OF SURFACE VELOCITY

We established our base camp 683 yards from the forefoot on July 10, altitude 5,300 feet. The site, on the top of a high bank, commands an excellent view of the broad flat tongue completely filling the valley bottom, and of the sharp peak of Mt. Freshfield (10,945 feet) rising over it in the background five miles away. Around the trunk of an evergreen tree on the edge of the bank a white band was painted to serve as a station in the instrumental triangulation. A stream of clear water lies at the foot of the bank.

After a trip up the three-mile tongue, a suitable location, 1,250 yards above the end of the glacier, was chosen for establishing a line across the surface of the ice. The mark for the northern end was a rectangular slab of rock a rod square, perched on the inner slope of the north lateral moraine 50 yards above the glacier. It is one of the most prominent boulders anywhere on that side of the valley and is visible from nearly all parts of the northern half of the lower glacier. It is also visible from Camp Station, being about one and one-quarter miles distant therefrom. It is tilted towards the glacier and is the largest stone to be seen near the top of the lateral moraine from that standpoint. It is designated Station A. Owing to lack of time it was not painted. The mark for the southern end of the line was a much smaller boulder 125 feet above the edge of the ice on the crest of the south lateral moraine near the base of a prominent gully that scars the valley wall. A vertical reference line was painted on the side towards the glacier. It is designated Station B.

On July 13, Station A was occupied with the instrument. Fourteen numbered flat stones were carried out on the glacier and set in flat-bottomed niches chipped in the ice, 50 paces apart, on the line indicated by the vertical hair of the telescope, in accordance with signals from the observer. Such stones, particularly if dark in color, have a tendency to become fixed in the ice through melting. The writer has set out three of these lines, and has never had reason to suspect that any stone slipped from its original position. If one side of the stone is straight, it gives a good fiducial edge upon which to sight with the instrument. The azimuth and angle of depression of each stone were determined from a second station on the north moraine, later ascertained to be 320 feet distant. On line A-B the ice was 1,133 yards wide.

The positions of the stones are shown on the accompanying cross-section of the glacier (fig. 1). The estimated thickness of the ice is based upon the assumption that the gradient of the valley floor obtaining below the forefoot continues uniformly back under the ice. According to the configuration of the valley hereabouts, this does not seem unwarranted. The slope is about 125 feet to the mile and the maximum thickness of the glacier at the line of stones works



SECTION OF FRESHFIELD GLACIER ON LINE OF STONES

Horizontal and Vertical Scales in Feet

0 100 200 300 400 500

FIG. 1.

out at 400 feet. The longitudinal section is also constructed on the assumption that the valley bottom continues back at the same gradient of 125 feet per mile, the surface slope being plotted from the contours of the government map. Although this basal gradient is purely hypothetical, it probably is fairly approximate to the truth on this particular tongue, where the evenness of the surface and its comparative freedom from crevasses are strong indications of a smooth, regular valley floor beneath. The average slope of the similarly situated Forbes Brook valley adjacent, is 160 feet per mile.

Six days later (July 19) Station A was occupied again and the line re-determined on the ice which had meanwhile moved downward. The amount each stone had advanced was measured directly with a tape. The results are given in the following table:

Observations on a Line of Stones Set Across the Freshfield Glacier July 13, 1922

Stations	Distance from north margin of glacier	Motion from July 13 to July 19	Average daily motion for six days	Remarks
On north lateral moraine	*Ft.*	*In.*	*In.*	
A.	255	0	0	Superficial moraine extends from ice margin out on glacier about 400 feet.
1	420	24	4.00	
2	610	18	3.00	
3	775	25	4.17	
4	950	26	4.33	
5	1125	18	3.00	
6	1305	26	4.33	
7	1450	22	3.67	
8	1620	27	4.50	
CENTER OF GLACIER				
9	1800	26.5	4.42	
10	1990	24	4.00	
11	2175	28.5	4.75	
12	2285	28.5	4.75	
13	2500	29	4.83	Maximum motion.
Superficial moraine begins and extends 850 ft. to margin of glacier.				
14	2600	23	3.83	
On south lateral moraine				
B.	3600			200 feet from ice margin.

Approximate width of glacier on line of stones, 3400 ft.
Distance between stations marking the line, 3855 ft.

The increased average velocity of the southeasterly portion of the glacier as compared with the northwesterly portion is doubtless due to the fact that on the former side the ice is sweeping through a broad arc, which normally has the effect of deflecting the zone of most rapid motion away from the middle. When, as here, the curve is associated with a reversed curve further upstream, the deflection, following the analogy of running water, naturally would be more pronounced. And so, in fact, we find it here, the zone of maximum velocity being thrown far over towards the southeasterly margin. Actually it occurs about half-way between the center and the side instead of at the center.

The weather during the period of our stay was generally warm and pleasant, although windy and smoky, the smoke at times settling down in a dense pall almost obscuring the sun and hindering both mountaineering and photography.

2. INSTRUMENTAL TRIANGULATION FOR LOCATION AND MEASUREMENT OF A LINE OF STONES AND FOR EFFECTING CONNECTION WITH THE GOVERNMENT MAP

Conditions for the laying off of a base-line on the surface of the ice were not very favorable in the neighborhood of the line of stones, but after some search a location was finally chosen, 400 yards upstream, and a level line 270 feet long was measured with a steel tape. Observations from this gave the distance (3,855 feet) between Stations A and B at the ends of the line.

From these the position of the great boulder (pl. 1, fig. 1) on the surface of the ice near the center of the glacier was determined. On July 19 the downstream edge of the boulder was 2,440 feet distant from Station A, and 2,510 feet distant from Station B, the elevation of its base being 6,000 feet. The azimuths between the boulder and the ends of the line were: from A, 39° 10′, and from B, 38° 10′. It is visible from Camp Station, and distinctly appears in plate 3, figure 2, $1\frac{5}{16}$ inches from the left edge on the ice profile.

This boulder is the largest of many sizable erratics that are scattered over different quarters of the tongue. They occur singly and sometimes in pairs, surrounded by clean white ice. This gives them good visibility from a distance and will render them valuable markers for studies of the ice motion. The stone in question was doubtless noticed by Dr. Collie in 1897, for it appears to be shown in the illustration opposite page 62 in his "Climbs and Explorations in the Canadian Rockies." He writes (page 55), "We noticed them within a mile of the snout of the glacier and in 1902 they did not seem to have moved much." The rock is now exactly a mile from the end

1. Great boulder on surface of Freshfield Glacier looking north. Photograph by J. M. Thorington.

2. Glacial erratic marked "1922." Photograph by J. M. Thorington.

Test view of tongue from rock " C," showing rock " H," July 20, 1922. Glacier is 1,000 feet distant. Photograph by H. Palmer.

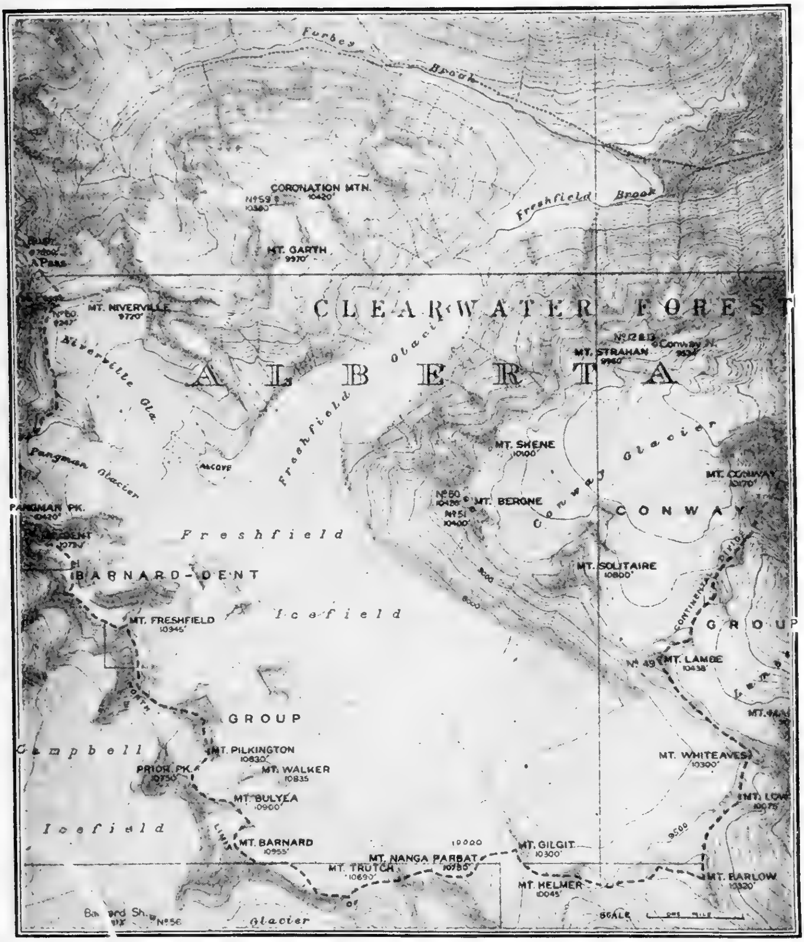


FIG. 2.

Reproduced from Sheet No. 18 of the Interprovincial Boundary Commission.

of the glacier. Its dimensions are estimated to be 36 feet long, 18 feet wide, and 16 feet high. The cubic contents would be about 10,000 cubic feet. With some difficulty, it was climbed by Feuz, who erected a little cairn on the downstream point out of loose fragments found on the top. It was not otherwise marked.

Another of these stones was utilized as a marker for one end of the base line (pl. 1, fig. 2). It was painted "1922" with white paint, and lay 350 feet distant from the block just mentioned. The distance to Station A was computed to be 2,080 feet, and to B, 2,580 feet, the elevation being 5,960 feet. The azimuths between this boulder and the ends of the line were: at A, 38°45′, and at B, 30°25′.

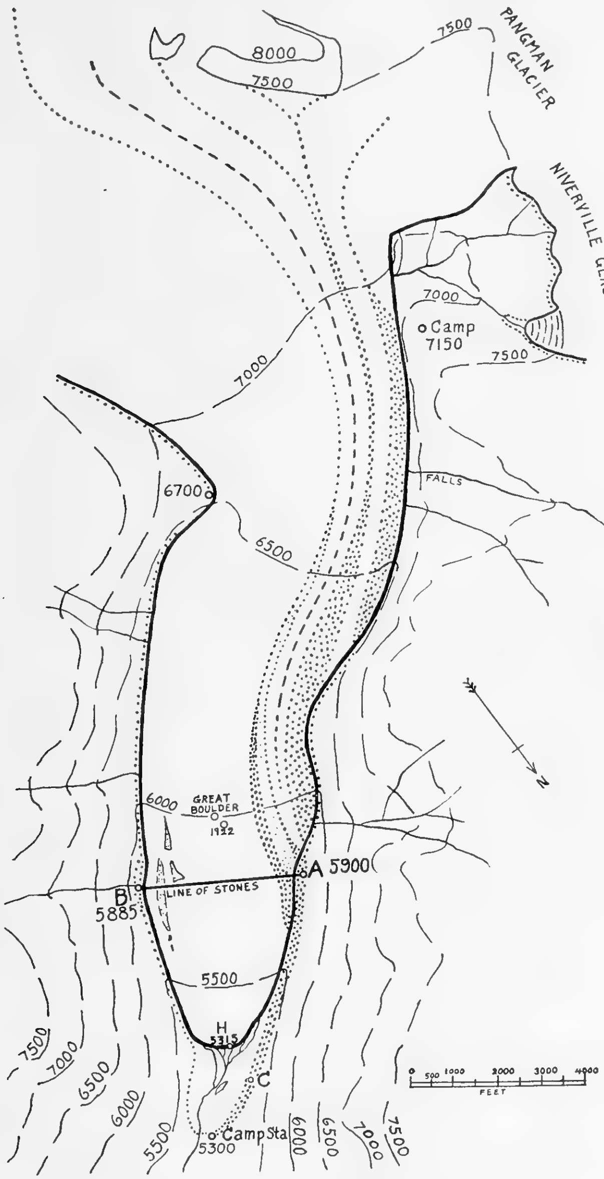
From Stations A and B, Mt. Freshfield, Mt. David, and other points on sheet 18 of the Boundary map were observed as controls.

3. OBSERVATIONS ON THE TONGUE AND ITS RETREAT

It was originally intended to make a detailed photographic survey of the terminal ice tongue and the area adjacent, but this had to be abandoned on account of the density of the smoke. A local secondary triangulation, however, was carried out by the writer from a 305-foot base, measured on the out-wash plain near camp. By this means a boulder at the ice lip (H in pl. 2) was located, together with several other features of importance, including a large stone on the north lateral moraine to serve as a station for test views of the tongue.

This rock is designated Station C. It was marked on the side towards Camp Station, from which it is distant 505 yards, with a three-foot cross (X) in white paint. The cross is visible from Camp Station, but only upon careful scrutiny and with glasses. The stone rests on the only sizable exposure of bed-rock on the north side of the valley, about 45 feet above the flat ground moraine. It lies just to the left of and above an oval-topped reddish stone plainly to be seen from Camp Station. It was occupied with the camera July 20, and the accompanying view secured (pl. 2).

There is no question but that the glacier is retreating. The actual end is a thin, semicircular, concave lip, furrowed with the typical longitudinal depressions almost universally associated with this condition. The frontal slope varies between 20° and 30°. As regards the rate of retreat, there seem to be no precise data available. However, the writer is fortunate in being able to present a view (pl. 3, fig. 1) of the tongue secured by the late Hermann Woolley on the occasion of his visit in 1902. Almost certainly this was taken very close to Camp Station, and when compared with a similar photo-



THE TONGUE OF FRESHFIELD GLACIER

Showing Moraines, Stations and other Details from a Local Survey by
HOWARD PALMER 1922
Adjusted to Sheet 18 of the Alberta-British Columbia Boundary Commission

FIG. 3.

graph of 1922 (pl. 3, fig. 2), exhibits a marked shrinkage and recession. The view of 1902, taken in connection with another of that year (not reproduced) leaves little doubt but that a certain pile of moraine (marked M in the 1922 picture) was then in process of formation at the ice lip.[1] Assuming this to be true, this pile of moraine being 925 feet distant from the most advanced ice in 1922 allows an estimate to be made of an average retreat of 46 feet per year for the 20 years intervening. A distant photograph by the Boundary Survey (pl. 4, fig. 1) taken in 1918 plainly shows the presence of this same moraine pile, although the exact position of the ice front in relation to it cannot be satisfactorily fixed.

The inner slopes of moraine and gravel bounding the open space below the tongue have not had sufficient time, since the ice was near, to develop any forest. A scattering of trees and bushes is growing up, but none have reached large size and there is far from being a continuous mat of vegetation. The 1902 picture above referred to indicates that there has been only a slight increase in the amount of vegetation on these slopes in the score of years intervening. One is probably safe therefore in estimating a lapse of at least half a century since the ice abutted against the banks in question. It was regretted that opportunity was wanting for a detailed study of this question by the cutting of trees. No growth whatever was noticed on the ground moraine of the valley floor below the tongue. The rapid cutting of the migratory glacial streams would perhaps account for this.

In the test photograph (pl. 2) taken from Station C, three fair-sized stones may be noted near the edge of the ice. These should constitute helpful markers for the future. The one most advanced (H in pl. 2) lies exactly at the ice margin and is located on the accompanying map of the glacier tongue. It is distant 683 yards from Camp Station and is marked H on the map (fig. 3).

Drainage streams emerging at several points along the forefoot soon unite in a powerful torrent which cuts off the southeasterly side of the valley and prevents access to the surface of the ice except at

[1] It is possible that the moraine may have been formed in 1897 with almost no retreat between 1897 and 1902, for Professor Collie, at page 56, in his book already cited, states (referring to his visit in 1897), "The snout of the glacier was advancing and plowing up the debris before it." The weakest point in the deduction is the difficulty of identifying the moraine so plainly seen in figure 1 of plate 3 with that marked in figure 2, but it is the writer's opinion, after examining the place, that they are the same.

1. Photograph of the tongue taken from near Camp Station by Hermann Woolley in 1902. Mt. Freshfield in distance.

2. Tongue of glacier from nearly the same point as figure 1. Photograph by J. M. Thorington, 1922.

Both photographs cover exactly the same field and are reproduced on exactly the same scale. The greater apparent massiveness of the glacier in figure 1 is largely due to the fact that it is upwards of 300 yards nearer to the camera. Its skyline therefore conceals more of the distant mountains than does that of figure 2. The difference in the aspect of the two is probably due as much to perspective as to the actual shrinkage of the ice in the 20 years intervening.

Mt. Pilkington, 10,830 ft. Mt. Freshfield, 10,945 ft.

1. General view of tongue from Mt. David. Photograph by Alberta—British Columbia Boundary Commission, 1918.

2. The northerly portion of the glacial basin from about 8,000 feet. Lateral depression in central distance, with tongue of Niverville Glacier behind. Pangman Glacier to the left. Compare plate 7, figure 1. Photograph by H. Palmer.

the extreme right. Apparently the tongue does not produce a terminal ice arch or cavern.

The vertical shrinkage of the three mile tongue has been enormous, according to the indications of the most recent lateral moraines. In the lower portions of the valley these moraines rise more than 100 feet above the ice. There is no terminal moraine, properly speaking. The tongue, as well as the upper plateau of the glacier, is singularly free from superficial moraines. The medial moraines of the trunk mingle with the northwesterly lateral and do not extend within a mile of the forefoot.

4. GENERAL FEATURES OF THE GLACIER

The main reservoir or collecting area of the glacier is a broad, fan-shaped basin with a flat floor that occupies a distorted synclinal fold on the axis of the main range of the Rockies. The dissipator tongue discharges at right angles in the position of the handle of the fan. The dip and direction of the northeasterly limb of the syncline are remarkably constant, so that the ice flows along a nearly straight line on this side. The inner slopes of the basin here are practically snowless, affording little, if any, nourishment to the trunk stream. The southwesterly limb is a loftier and more abrupt folding, with a greater shattering of the strata and a greater irregularity of sculpture. Here are the culminating summits of the group, and from them descend in broken ice falls many smaller tributary glaciers.

The trunk glacier takes its source on the inner slopes of the southerly wall of the basin, a ridge 9,500-10,000 feet high, stretching for six miles between Mts. Barnard and Low. Here, broad, unbroken, gently tilted inclines afford ideal conditions for glacier alimentation. In the first three miles the snow fields descend to 8,000 feet, where, as nearly as may be judged, the snow-line occurs. The next three miles are a wide icy plain, flat and level to the eye, but really descending a thousand feet, designated on the map the "Freshfield Icefield[1]" (pl. 4, fig. 2, and pl. 5, figs. 1 and 2). Hereabouts the medial moraines, so prominent half-way down the tongue, begin to appear along the westerly side. On the diagram, figure 3, they have

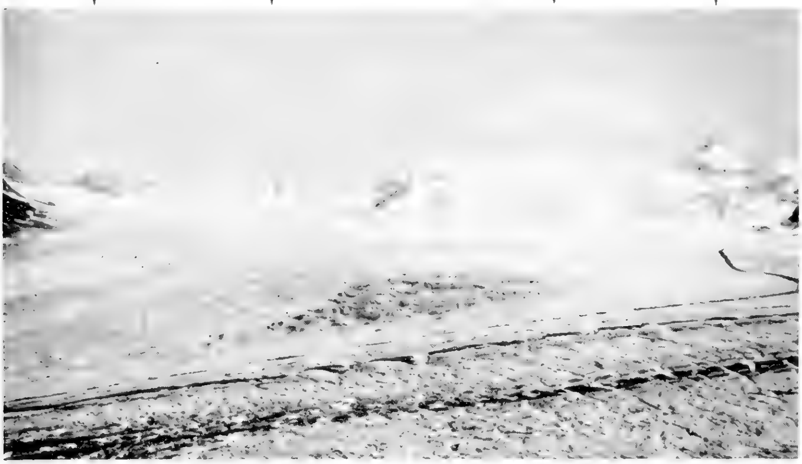
[1] The writer deprecates the use of "icefield" as commonly employed in connection with valley glaciers. It tends to obscure the fact that the "icefield" is only a portion of an advancing body of ice. Emphasis needs to be laid on the fact that a glacier is a distinct entity, with a definite locality of origin and a definite place of termination, between which the ice mass moves in an orderly progression. We do not so easily or so harmfully call the slack water of a river, "lake."

been sketched in from photographs, giving a graphic picture of the relative importance of the tributaries as sources of ice supply. Compared to the size of the ice system, they are small and scanty (pl. 6, figs. 1 and 2). They do not anywhere pile themselves up into lofty continuous ridges. Their prominence is due chiefly to their lineal distinctness and lack of wide dispersion over the surface of the ice.

The northerly segment of the basin, beyond the discharge tongue, contributes scantily to it (pl. 7, fig. 1). Owing to various causes, but chiefly to a more direct exposure to the sun, melting has exceeded the snow supply and the ice is in an essentially stagnant condition. Three commensal streams occur here: the Niverville and Pangman glaciers, and another without a name which issues from a deep precipitously walled cirque on the north side of Mt. Freshfield. Judging from its position and length, this is the most vigorous of the trio. At the corner where the main tongue issues from the basin, the Niverville and Pangman glaciers, in receding to the higher slopes, have uncovered a portion of the trough floor and a little upland valley filled with rushing streams and bordered with ice tongues. (See pl. 7, fig. 2 and pl. 4, fig. 2.) Thus there has been produced a lateral **U**-shaped alcove, across the open end of which the main body of ice flows, exposing a section about 75 feet thick and 500 yards wide. Its position has been indicated on the map (fig. 2).

Such depressions are not uncommon features of valley glaciers. They often give rise to marginal lakelets, as the Marjelen See on the Aletsch Glacier. But this particular one possesses the peculiarity of occasionally being filled by an offshoot from the main ice field in the shape of a secondary tongue. Although at the time of our visit in 1922, it was entirely bare of ice, in July, 1918, the Boundary Survey photographs show that it was filled to the brim with shattered ice fragments in the nature of icebergs or seracs. (Note even line of vegetation at level of main glacier in pl. 7, fig. 1. This would seem to be an " ice-line " corresponding to the waterline in the case of a lake.) The accompanying photograph, taken in August, 1913 (pl. 8, fig. 1), indicates that not long before an ice invasion had also occurred here, as many wasting pillars of glacier ice were scattered about on the floor of the alcove. Thus, the place appears to serve as a kind of safety valve, which relieves pressure on the constricted dissipator whenever the snow-fall on the mountains to the south and west has accumulated beyond the dissipator's capacity for prompt discharge.

The writer spent an afternoon visiting the locality and in photographing the ice wall at close quarters. Another secondary tongue seemed to be forming, for the wall had thrown forward several



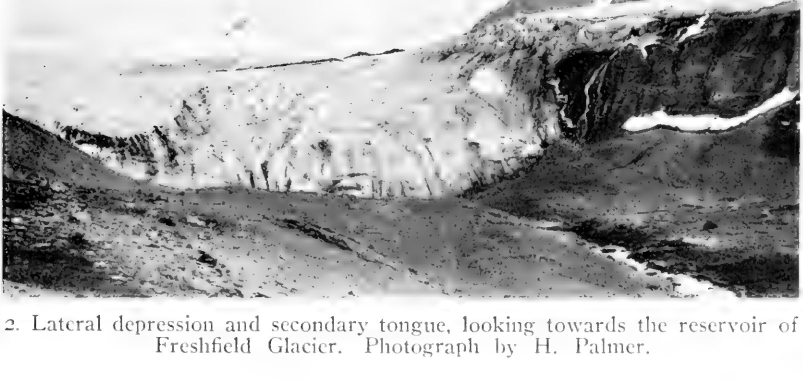
1. Gathering basin of Freshfield Glacier looking southeasterly. Sky line is Continental Divide. Photograph by E. Feuz.

2. Gathering basin of Freshfield Glacier as seen from promontory below advanced camp. Ice at right slopes down into lateral depression. Compare plate 7, figure 2, which is an approximate continuation. Photograph by H. Palmer.

1. Surface of the glacier tongue near advanced camp. Photograph by H. Palmer.

2. Mt. Nanga Parbat and Mt. Trutch, showing upper ice plateau; snow line in distance (compare pl. 5, fig. 1). Telephotograph by H. Palmer.

1. Part of the lateral depression as seen from the main glacier adjacent, looking northwesterly. Note even line of vegetation to which alcove is filled with ice. Photograph by H. Palmer.



2. Lateral depression and secondary tongue, looking towards the reservoir of Freshfield Glacier. Photograph by H. Palmer.

1. Serac remaining in lateral depression after last advance of secondary tongue. Photograph by E. Feuz, August, 1913.

2. Ice advancing into the lateral depression, 1922. Photograph by H. Palmer.

blocks of ice, a distinct nose projected at the center, and a push moraine four feet high had been raised along the base of the wall (pl. 8, fig. 2). Another push moraine was noted 150 feet in front of the ice, apparently indicating the termination of the last advance preceding.

We thus have evidence that advances occurred here in about 1912 and 1918 and that another might soon be expected, perhaps in 1923. Can it be that this is a periodic phenomenon? It would be a very interesting matter to determine.

The floor of the alcove consists of comminuted shingle and well-broken ground moraine (see pl. 8, fig. 1). A ridge of slaty, well-scored, bed rock occurs in the center where the nose is advancing. The drainage stream from the upper glacier basin flows under the ice wall here. No signs of a lake in the alcove were to be detected.

For so great an expanse of ice, there are singularly few large crevasses and ice falls. One can wander about almost at will without serious hindrance. At the easterly corner where the tongue leaves the basin, occurs the only notable ice fall in the glacier proper. Here a 300-foot cliff breaks the floor of the basin and gives rise to a steep and interesting ice cascade of this height (pl. 9).

No considerable drainage streams were noted on the tongue or upper icefield, although small brooks of course run everywhere. The water soon finds its way beneath the ice through numerous moulins.

The rock surrounding the Freshfield glacier is mainly dark, slaty limestone, fossiliferous in places. About two miles above the forefoot a crushed and crumpled anticlinal arch is very well displayed in the rocks of the gorge on both sides of the valley.

SUMMARY OF GLACIER MEASUREMENTS AND OBSERVATIONS IN THE CANADIAN ALPS, WITH REFERENCES

This note aims to present a brief digest of what has been done in the way of glacial measurements and study in the Canadian Alps. Not every individual report has been listed, but the titles here brought together represent the main body of the literature and will supply materials for an exhaustive study by anyone interested.

The most complete and comprehensive single publication dealing with the glaciers of the Canadian Alps is the monograph entitled, "Glaciers of the Canadian Rockies and Selkirks," by W. H. Sherzer, published by the Smithsonian Institution in 1907. (Contributions to Knowledge, Vol. XXXIV, Publ. No. 1692.) It is handsomely illustrated and contains 135 pages. The glaciers studied were the Victoria, Wenkchemna, Yoho, in the Rockies, and the Illecillewaet and Asulkan in the Selkirks, the period covered being between 1902 and 1905. About half the space is devoted to the Victoria glacier. See also "Nature and Activity of Canadian Glaciers," by W. H. Sherzer, Canadian Alpine Journal, Vol. I, No. 2, pp. 249-263. Another general discussion of the glaciers in the Canadian Rockies and Selkirks is contained in a paper "Notes on Glaciers," by A. O. Wheeler, Canadian Alpine Journal, 1920, Vol. XI, pp. 121-146.

Detailed studies of the surface velocity and frontal retreat of the Illecillewaet glacier were made over a long period by Messrs. George and William S. Vaux, and continued by Miss Mary M. Vaux. See the following articles: "Glacier Observations," by George Vaux, Jr. and William S. Vaux, Canadian Alpine Journal, Vol. I, No. 1, 1907, pp. 138-148, with map; "Observations on Glaciers, 1909," by George Vaux, Jr., Can. Alp. J., Vol. II, No. 2, pp. 126-130; "Observations on Glaciers, 1910," by Mary M. Vaux, Canadian Alpine Journal, Vol. III, p. 127; "Observations on Glaciers," by Mary M. Vaux, Canadian Alpine Journal, Vol. V, p. 59. These papers also report observations on the Asulkan glacier.

The surface velocity and retreat of the Yoho glacier were observed continuously between 1906 and 1919 by A. O. Wheeler, and reported in the pages of the Canadian Alpine Journal, Vol. I to Vol. XI. See Vol. XI (1920), p. 182, for a summary of these observations and measurements.

The only other glaciers that have been studied are the Robson, the Sir Sandford, and the Freshfield. Descriptions and measurements of the retreat of the first named are reported in the following papers: "Geology and Glacial Features of Mt. Robson," by A. P. Coleman, Can. Alp. Journal, Vol. II, No. 2, pp. 108-113; "Robson Glacier Measurements," by A. O. Wheeler, Can. Alp. Journal, Vol. IV, 1912, pp. 44-45; "Robson Glacier," by A. O. Wheeler, Can. Alp. Journal, Vol. VI, 1915, p. 139; "Motion of Robson Glacier," by A. O. Wheeler, Can. Alp. Journal, Vol. XIII, 1923, p. 158. No measurements of surface velocity have been performed on the Robson glacier.

The Sir Sandford was mapped and observed by the writer in 1910. The next year its surface velocity was measured. See "Observations on the Sir Sandford Glacier, 1911," Geographical Journal, May 1912, Vol. XXXIX, pp. 446-453. Work was continued in 1912, the surface velocity being redetermined on the same line. See "Mountaineering and Exploration in the Selkirks," by H. Palmer, Putnam, 1914, pp. 376-391.

Crest of the ice cascade at the southerly corner of the tongue. Photograph by H. Palmer.

Tabular Summary of Glacier Observations in the Canadian Alps, 1899-1922

ROCKIES

Glacier	Frontal Recession	Surface Velocity Maximum	Surface Velocity Minimum	Remarks
		(Inches	per diem)	
Victoria	1899-1912. 14 ft. per year	2.165	.005	Period of 423 days, 1904-1905.
Yoho	1906-1918. 33 ft. per year	5.03	3.09	Average, 1906-1918.
Freshfield	1902-1922. Estimated at 46 ft. per year	4.83	3.00	Summer motion for 6 days, 1922.
Robson	1911-1922. 22.1 ft. per year	....	....	No measurements.

SELKIRKS

Glacier	Frontal Recession	Surface Velocity Maximum	Surface Velocity Minimum	Remarks
Illecillewaet	1898-1906. 33 ft. per year	5.65	3.21	1899-1903.
		11.33	7.00	Summer motion for 12 days, 1906.
	1898-1912. 40 ft. per year	6.73	2.45	Period of 396 days, 1906-1907.
		5.13	1.34	Period of 342 days, 1909-1910.
Asulkan	Intermittent.	3.13	1.13	Period of 398 days, 1906-1907.
		8.90	2.40	Summer motion for 10 days, 1906.
Sir Sandford	1909-1910. 25 ft.	6.73	1.36	Summer motion for 15 days, 1911.
	1910-1911. 37.3 ft. in 50 wks.	6.25	3.15	Summer motion for 11¾ days, 1912.
	1911-1912. 54 ft. in 51 wks.	....	....	

(Note.—The writer estimates the total frontal recession of the Illecillewaet glacier between 1887 and 1923 as upwards of 2,000 feet.)

So far as the writer can ascertain, all the glaciers in the Canadian Alps are now in a phase of retreat. Certainly all that he has personally observed in the last 15 years are in this condition. Among them may be mentioned the following:

Swift Current	Victoria
Fraser	Sir Sandford
Columbia	Adamant
King Edward	Goldstream
Serenity	Palmer
Coronet	Illecillewaet
Unwin	Asulkan
Nameless (at S. end Maligne Lake)	Geikie
	Bishops
Conway	Deville
Freshfield	Battle

The Wenkchemna glacier has been reported to have exhibited signs of advance during this period, but the writer has not seen it. The Clemenceau, a very large glacier situated southwest of Fortress Lake, is recently reported to be essentially stagnant at an advanced stage, close up to its terminal moraine. It does not appear to have receded at all for a long period.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 76, NUMBER 12

"ADAPTATIONS" TO SOCIAL LIFE: THE TERMITES (ISOPTERA)

(WITH THREE PLATES)

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(PUBLICATION 2786)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
SEPTEMBER 2, 1924

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

"ADAPTATIONS" TO SOCIAL LIFE: THE TERMITES (ISOPTERA)

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INTRODUCTION

GREGARIOUS LIFE

Many insects are gregarious feeders, Lepidopterous and sawfly larvae, Hemiptera, and Orthoptera furnishing notable examples. Others live together in large numbers, possibly due only to the fact that the eggs were laid in a mass or close together, as in the case of certain wood-boring beetles; these are mere temporary associations. Again, certain adult insects congregate solely for the purpose of mating; for example, mayflies, mosquitoes, and gadflies. Particularly striking is the habit of the large gadfly (*Tabanus americanus* Forster) as noted by Mosier and Snyder in the lower Florida Everglades where the males congregate in enormous numbers to mate with the females just before dawn. Still other insects have the habit of congregating in large masses for special purposes; for example some Lepidopterous larvae which build webs and live together in them for protection. But in practically all cases, except among the true social insects, the congregating is more or less temporary and is due to hunger, sex or fear, or to combinations of these elemental motivations, although sometimes caused by undue increase in numbers and the necessity for migration. In but few instances can there be traced any modifications which one could say result from such a life.

THE DAWN OF SOCIAL LIFE

In a few exceptional cases, notably among wood-boring insects, there is really a beginning of a true social or colony life and this can be seen in the case of some of the roaches, the wood-boring beetle, *Parandra brunnea* Fab., the pædogenetic beetle *Micromalthus debilis* Lec., and species in the peculiar order Zoraptera, in which there appears to be the foundation of a caste system.

Lameere has noted that it is among wood-boring insects that there is most frequently encountered an association of the two sexes for raising the young.

Roaches of the genus *Dasypoma* of North America live in rotten wood, and males and females are found together with the young. According to A. N. Caudell, of the U. S. National Museum, in the case of roaches in the genera *Salganea* and *Panestehia,* a break often occurs following in general the anal sulcus at the base of the wing, as at the humeral suture of termites, where the wing breaks off after the colonizing flight; in the primitive termites this suture is also often poorly defined. It is also interesting to note that roaches and termites mate in a similar manner. Roaches and termites were probably derived from the same primitive group, the Protoblattoiden of Holmgren, but the termites became more highly specialized. However, the North American roach, *Cryptocercus punctulatus* Scudd., is found wingless as a wood borer in decayed logs; it is in the same family as the genera *Salganea* and *Panestehia.*

Even in the most primitive termite, *Mastotermes darwiniensis* Frogg., the winged form of which is roach-like, social life has "resulted" in a soldier form which is much more specialized than would be expected. The most primitive and largest species of *Kalotermes* (*occidentis* Walker of North America), like all the other lower termites of the family *Kalotermitidae,* has not gone so far in its social adaptation, namely the subdivision of labor and caste formation, that more than one neuter form exists—a soldier in which vestigial wings are always present (pl. 3, fig. 1). Indeed Holmgren established a new genus, *Pterotermes,* for this termite. In many other species of *Kalotermes* and *Kalotermitidae,* vestigial wings occur on soldiers, but only occasionally.

In *Parandra* the eggs are inserted in the solid wood close together and I have observed that adults often mature and mate in wood underground in the bases of telephone poles, etc., without coming above ground and flying about before copulation. The adults are shy and shun the light when found in the open.

Micromalthus debilis Lec. is a remarkable wood-boring insect with a complex life cycle; the first stage larvae are found in wood in a semi-gregarious condition. Pædogenesis undoubtedly enables this insect to continue to live in this semi-social state even in wood below ground independent of the usual flight of winged forms before mating.

Species of *Zorotypus,* in the order Zoraptera of Silvestri are gregarious, and these very active little insects live under conditions very similar to those in which termites are found, often occurring in the galleries of the slower-moving termites, the young of which they greatly resemble. In addition to this social life, Snyder has noted that species of *Zorotypus* have apterous as well as the winged reproductive forms; the latter individuals lose their wings in a manner similar to the lower termites—the point of breakage being poorly defined—before rearing their young in runways under bark on dead trees, logs, etc., where it is moist. The apterous reproductive forms differ with the species; in one species (*snyderi* Caudell) they are darkly colored, with ocelli; in another (*hubbardi* Caudell) they are colorless and without ocelli, as are the nymphs or young. These apterous adults are present in their colonies in large numbers, as in the case of termites, and undoubtedly polygamy exists, as it does among termites. As in the case of termites, species of *Zorotypus* pass the greater portion of their lives in the dark. Undoubtedly *Zorotypus* is at the dawn of social life.

SOCIAL LIFE

Certain other insects—the social insects, such as ants, bees, wasps, and termites—live permanently together in more or less fixed communities or colonies. The basic "adaptations" to social life are found in the caste system. Here the specialization follows a more or less closely adhered-to division of labor with forms better and often strikingly fitted for the principal purposes of life as feeding, reproduction, and protection. I shall refer only to termites.

THE TERMITES (ISOPTERA)

Termites live together in well-organized communities or large colonies in wood, in the ground, in mound nests, or in carton tree nests. There are marked differences in their life from that of other social insects. Termites have an incomplete metamorphosis; there is no true pupal state, but resting or quiescent stages occur during molting. There are always present in termite colony life, winged, colonizing, sexual forms (appearing each season at a definite period in well-established colonies), soldiers or workers, or both, of both sexes but sterile (neuters) and at least one pair of parent reproductive individuals (pl. 2, figs. 1 and 2). Again, the termite colony is not a feminist society—there are "equal rights" for the male. Both the male and female parent termites feed and care for the young in incipient colonies; their first progeny are *not* always neuters, however, although this is true in some genera; and most of the primitive termites (family *Kalotermitidae*) have no worker caste. The male continues to live with and fertilize the female, and both have a post-adult growth—remarkable in the case of the queens of the more specialized family *Termitidae*. Both of these reproductive forms are long lived.

In case of the absence of parent reproductive forms of the winged caste, brachypterous (pl. 2, figs. 3 and 4) or apterous (pl. 2, figs. 6-8[1]) reproductive forms of both sexes are present; these forms are distinct castes. There are no fertile workers or soldiers among termites. Among the higher termites the neuters are polymorphic; there may be from one to three different types of soldiers and one to two types of workers of the same species.

The castes of termites, however, vary with the family and genus as does the progeny of a single pair of termites. The character of the progeny and the definite ratio between the castes also vary with the genus and the age of the colony. Hence, a genetic formula for termites would vary with the genus and age of the colony; the first brood of the incipient colony in some genera consists entirely of neuters. It would take years of study and experimentation to work out such a formula.

In no case at the present day do termites exist which do *not* produce as their progeny other castes in addition to the winged, sexual forms which must have been their presocial ancestral condition, *i. e.,* a single male and female sexually associated.

All the castes of termites are determined in the germ plasm of the species and are due to its inherent properties. As Thompson states, they are "segregants, in the sense of the offspring of *Oenothera lamarkiana,* arising generation after generation by the splitting and recombination of the genes of a heterozygous parent form." Hence the varied modifications among termites really are *not* due to "*adaptations*" to environment but let us rather say that favorable modifications have *persisted.*

The social life among termites must have begun some time before the Tertiary period, since wingless, sterile castes have been found in gum copal of the late Tertiary period, *i. e.,* polymorphism existed during the late Tertiary period; winged termites occur in the shales of the Tertiary period.

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[1] This illustration of a remarkable apterous form from Java may be compared with the nymph of the first form of the same species (pl. 2, figs. 9 and 10) and with the normal apterous form of *Reticulitermes flavipes* Kol. illustrated in Bull. 108, U. S. Nat. Mus., figure 63, p. 108 and plate 30, figure 2.

Adaptations to social life among the termites can be seen most clearly by their responses to the three primal urges—hunger, sex, and fear. Unlike man, with a double nervous system, insects have no inhibitions.

HUNGER

Lameere has attempted to prove that the neuters of the social insects are of trophogenic origin, *i. e.,* the germinative plasma is labile and is influenced by nourishment. His data on termites are, however, drawn from erroneous sources; the neuters of termites are of blastogenic origin, *i. e.,* there is a distinctive germinative plasma. Although differentiated, nevertheless no caste of any termite is *externally* clearly differentiated at the time of hatching from the egg.

The male and female parent termites share the "royal cell" in incipient colonies and eat wood as food and care for the young until the latter have developed to the point where they can feed themselves. In genera where the first brood consists entirely of neuters, they are of smaller size than those in well-established colonies. In genera where no workers exist (in the family *Kalotermitidae*) the nymphs of the sexual forms perform the duties of the workers. As the colony grows in size the workers or nymphs care for and feed the reproductive forms; the male lives on and repeatedly fertilizes the female. Among the lower termites (*Kalotermitidae*) the queen remains always active (pl. 2, fig. 5) but queens of the higher termites (*Termitidae*) attain a huge size, become inactive and are more dependent, being often imprisoned in the royal cell. They become mere egg-laying machines, and there is a remarkable post-adult growth. The soldier termites have not mandibles adapted for eating wood and have to be fed by the workers or nymphs. The young of termites are also thus fed and cared for in special nurseries. There are two types of special foods—proctodeal (from the anus) and stomodeal (from the mouth).

In addition to these foods, all termites constantly lick exudate or secretions from the bodies of other termites. In their eagerness for exudate, a portion of antenna, leg or wing pad is sometimes bitten off a member of the colony. Termitophiles or guests are present in termite colonies and these serve as other sources of exudate and special food. Termitophiles occur even in colonies of the lower termites, where they are merely tolerated, but in colonies of the higher, more specialized termites, wonderful physogastric termitophiles occur and are eagerly cared for. Mushrooms are cultivated by species of the *Termes* group in the Tropics, in special beds or gardens (pl. 1, figs. 1-8). Termite diet is further varied by an occasional lapse from the normal pure vegetable food by a meal on a wounded, sickly or dead member of the colony, leading to eugenics, as pointed out by Wheeler. In assisting termites to shed their skins, the insect in the quiescent stage during molting is sometimes eaten by workers instead of merely the shed skin; probably this only occurs in the case of deformed individuals.

The chief diet of termites was always mainly cellulose from pre-social to the present times. In all termites except the higher forms, protozoa occur in the guts, and act as enzymes in aiding termites to digest the cellulose when in the form of wood; in mature queens the jaw muscles have degenerated, due to the fact that they are fed on partly digested food, and no longer masticate wood. It is among the higher termites that specialized foods play a more important rôle, and here the special wood-digesting protozoa are absent.

Having progressed thus far, restraining myself from using the much abused term "anthropocentrism," may I be permitted to state that, while termites have brains, and no one can deny but that there is undoubtedly a spirit of the colony or solicitude for the communal welfare, termites cannot be endowed with human reason. Thompson's work on the brains of termites has shown that the young are differentiated at the time of hatching and has proven that worker termites do *not* determine any caste by feeding. Furthermore, many of their instincts of care of the brood, etc., have purely selfish bases. I refer to worker *termites!* What can be said of the workers of the honey bee? Has their social specialization—or possibly domestication—enabled the honey bee (unlike the ants and termites) to make a study of dietetics so intensive as to place the control of the caste of the organisms to come in the hands of the feeding workers? I realize that careful work has been done by competent entomologists throughout the world on the honey bee. Nevertheless may I not make an earnest plea for an open-minded study, combining careful cytological work with experimentation with living colonies, to definitely settle whether or not the difference between the worker and queen of *Apis mellifica* Linn. is blastogenic? Whether an impregnated egg or a three-day-old worker can be developed into a queen by being fed upon the highly nutritious "royal pabulum," or being left in a smaller cell and fed meagerly, develop into a worker—the ultimate fate being subject, as Lull states, to the whim of the workers!

SEX

At certain seasons of each year, winged sexual, colonizing forms appear in well-established termite colonies, these forms having color in the body and having eyes. Normally termites shun the light, but these forms are impelled by some irresistible impulse to leave the parent colony and become markedly positively phototropic—a reversal of only temporary nature. As is necessary, the colonizing flight, or "swarming," is often correlated with rainfall, especially in arid regions. The lower termites have a longer, stronger flight and emerge from the parent colony in smaller numbers and at irregular intervals, while the more specialized species are restricted to a few large flights annually. The line of weakness at the base of the wings (where the wing breaks off after the flight) in the lower termites is often poorly defined, but is well defined in the higher termites which sometimes lose the wings in mid air, whereas the lower termites are forced to pry off the wings after alighting. In some genera the sexes are markedly attracted to each other before and after the flight or "swarm." The wings are lost and the males and females now exhibit marked thigmotropism; they burrow under pieces of decayed wood lying on the ground, under the bark on dead trees, logs or stumps, and in arid regions under dry cow chips, stones, etc. Mating does not take place while the insects are in the air and not until they have separated into pairs and together excavated a small "royal cell" and have fed on wood or cellulose in another form. Then the sex organs have matured and are ready to function.

The act of coition is *not* by superimposition; Haviland, not having observed coition, thought that the relatively small male must fertilize the eggs after they had been laid by the huge *Termes* queen; a *Termes* queen with markedly distended abdomen measures 100 mm. in length, 22 mm. in width and 20 mm. in height—the male is 16 mm. in length, 4 mm. in width and 3 mm. in height. However, superimposition in coition is unnecessary, since the sexes mate with the apices of the abdomens opposed. Termites again differ from all the other social insects in the continued cohabitation with and fertilization of the female by the male. Such repeated fertilization is necessary, due to the enormous number of eggs laid in large colonies.

Hence it has been noted that termites in the course of their specialization have lost the strong power of flight, for it is no longer necessary to seek "mates" afar, when they swarm in enormous numbers. The queens lose their power of locomotion after a slow but remarkable post-adult growth, to accommodate an enormous ovarian development.

It must not be understood that there is only one type of reproductive form—the winged—among termites. Various different types of reproductive forms are first evidenced among insects inclined to be gregarious, as in the aphids.

As one of the "adaptations" of reproduction in termites, due to social life, the use of accessory sexual forms should be noted. Both brachypterous and apterous sexual individuals occur, with a few intermediates. These forms, inasmuch as they appear incapable of producing the winged sexual forms, are extreme social specializations with their reproductive functions more nearly purely colonial (*i. e.*, of the parent colony in contrast to the winged colonizing adults) in purpose. Their inability to produce the winged sexual adult (capable of wider dissemination) shows to excellent advantage their social origin and accessory nature; they are present in numbers and often perform the duties of workers.

Brachypterous reproductive sexual adults or those forms with vestigial wings (wing pads of varying length) have been noted by Snyder in the genus *Reticulitermes* of eastern United States to make a short "pseudo-flight" at the same time that the winged colonizing adults were making their annual flight. It is possible that this appearance in the open with the winged forms is their normal method of emigration to form new colonies, although it may be that their chief method of dispersal is by subterranean galleries. However, they give every evidence of being positively phototropic; they have more or less color in the body and in some of the facets of the compound eye; they also have ocelli and are probably able to perceive light and direction by means of the reduced compound eyes and ocelli but probably not images. Possibly this is the manifestation of an inherited instinct to swarm; running about or short jerky jumps into the air is all that their wingless condition will permit; at this time their sex organs are ready to function.

Polygamy, or perhaps better promiscuity, also exists among the wingless forms as a result of the colonial life of termites (a few males occur among a large number of females), whereas the winged sexual adults are normally monogamous—a less rapid method of increase, especially in young colonies. Exceptions to this occur, as when the deälated sexual male adult, upon the loss of his mate, consorts with a harem of brachypterous females. Neither neoteny nor pædogenesis exists among termites.

FEAR

Ants are terrestrial and dominant creatures; termites, as a rule being blind and soft-bodied, are usually subterranean or secluded in habitat and never dominant. They have been forced to "dig in" to survive and underrun tropical countries. There are a few exceptions, such as in *Hodotermes* of Africa, where the workers are harvesting in habit and come above ground into the sunlight; these so-called "workers" and the soldiers have color in the body and have eyes. Ants being terrestrial and aggressive, use their mandibles, sting, and formic acid spray as weapons of offense as well as for defense. Termites have all their weapons located on the head; mandibles and repugnant frontal gland secretion are used merely for defense. Workers in some genera of termites effectively use their mandibles in the defense of the colony and are more effective than the soldiers.

Among the most remarkable "adaptations" to social life among termites are the variations in development of the mandibles and frontal glands in the soldier caste. Among the lower termites (*Kalotermitidae*), the mandibles of the soldier caste are normally adapted for biting (pl. 3, fig. 1), while the frontal gland is rudimentary. In many of the higher termites (*Termitidae*), the mandibles are absent or vestigial and the frontal gland is highly specialized. Indeed, in the family *Rhinotermitidae*, intermediate between the lower and higher termites, the frontal gland is a specialized organ of defense; in *Coptotermes*, a sticky, white secretion exudes from a short tube opening. In some genera of the *Termitidae* the secretion is exuded from a nasus or beak (*Nasutitermes*), (pl. 3, fig. 2) or from the labrum extended into an elongate slender tube forked at the tip (*Rhinotermes*), (pl. 3, fig. 4). In species of *Armitermes* there are both biting mandibles and a nasus (pl. 3, fig. 3). This pungent secretion is more effective against ants—the worst enemies of termites—than are mandibles; in the specialization of winged termites this gland has passed from a rudimentary, closed (or plate) to an open stage. In other genera (*Capritermes*), (pl. 3, fig. 6), *Mirotermes*, and *Orthognathotermes* (pl. 3, fig. 5)) the mandibles are sometimes markedly asymetrical or at least very elongate and twisted. These mandibles could not possibly be used for biting but they are made use of by bringing together and flipping or snapping particles of earth at the invaders or even flipping away the invaders themselves.

As Wheeler predicted in 1907, "wherever the habits of the soldiers have been carefully studied it has been found that their singular and apparently hypertrophied structures have a very definite function." Even where it seems most certain that there is a teratological development of the soldier head, it can be proven—even granting such an origin—that they have become exquisitely adapted to particular functions.

In the genus *Anoplotermes* the soldier caste is completely absent but it may be significant that the workers and winged forms often have very elongate mandibles (pl. 3, fig. 7). Species of *Anoplotermes* are often found living closely associated with termites having mandibulate soldiers, or in hard mound nests.

The lower termites (*Kalotermitidae*) and many *Rhinotermitidae* are entirely wood-boring in habit and live a protected life in dead trees, logs, and stumps. They are negatively phototropic to a marked degree, and when boring in logs they always leave a thin layer or shell of wood on the exterior. In one interesting case, *Cryptotermes thompsonae* Snyder of Panama, in making use of the exit holes of a wood-boring beetle, these holes were capped over or closed by the termites using a sticky substance and their pellets of excrement (pl. 3, figs. 10 and 11); this is rather unusual in the case of a Kalotermitid.

In addition to being subterranean in habit, many termites build carton, earth-like shelter tubes (pl. 3, fig. 8) when they desire to come out above ground or into the open. That is, they carry earth, their source of protection and moisture, with them above ground, over stones, up tree trunks, etc. Termites abandon colonies in wood that have been disturbed, emigrating through underground galleries—often to considerable depths; this also occurs to avoid extremes in temperature (and lack of moisture), particularly in arid or cold regions. Some species of termites of subterranean habit have subfossorial legs.

Among the *Termitidae* the nests are often architecturally perfect and nests of the Lower Congo have a regular system of ventilation. The meridional magnetic mounds of the compass termite of Australia and solid earthen mound nests hard enough to support the weight of a wild bull show specialization of a high degree. These towering hillocks—often like negro huts in considerable villages—(pl. 3, fig. 9) afford adequate protection to the immobile queens which are frequently of huge size. These queens are imprisoned in a royal cell, which in some nests is in the central portion near the base. The large carton semi-spherical " niggerhead " tree nests (pl. 3, fig. 12) of *Nasutitermes* are usually of tough texture; queens in these nests are not as large as those of *Termes,* seldom being over

25 mm. in length. Some species of *Anoplotermes* which are of subterranean habit build termitariums of soft earth-like substance (pl. 3, fig. 13); others are of hard texture.

CONCLUSION

It has been seen that the "adaptations" of termites to social life can be most readily traced in their reactions to the fundamental biological phenomena—hunger, sex, and fear. In fact, their colonial life has led or *permitted* individuals to become specialized for these primary purposes.

Social life through hunger impulses has led termites from a pure diet of wood (with protozoa in the guts necessary to the digestive processes) to several specialized foods solicited from each other and even to cultivate mushrooms and exudate-secreting insects; protozoa are then no longer necessary.

Among termites social life has led to unique expressions of sex urge. There is no nuptial flight where one male fertilizes one female at sacrifice of his life in the termites. There is a colonizing flight of an enormous number of males and females (large numbers of both sexes fail to survive) the male lives a long life with the female, and there is repeated fertilization. The progeny is composed of fertile and sterile forms, in definite relative ratios. A remarkable post-adult growth takes place in the queen, and she loses her power of locomotion. Several wingless reproductive forms have developed. Even the winged caste loses its strong power of flight and a suture has developed for the easy shedding of the wings after the flight. Polygamy and promiscuity result from communal life.

Social life has led or forced termites through fear, or desire for protection, to a subterranean existence; strong mound or carton nests have been developed, sometimes in trees, while carton shelter tubes have been utilized to cover forays above ground. As a result the eyes and color have been lost in the neuters and lost or reduced in the wingless reproductive forms; they either have become strongly negatively phototropic or thus merely avoid desiccation.

A wonderfully varied specialization is shown in the development of different types of mandibles and openings for the frontal gland, and a diverse polymorphism has developed among the neuters. Finally the soldier caste is lost in *Anoplotermes*.

EXPLANATION OF PLATES

PLATE I

HUNGER. TERMES GROUP. JAVA.

FIG. 1. Cross section of a termite comb showing "cauliflowers" on walls, ceiling and floor of passages as bright white granules.
FIG. 2. Small comb of termite.
FIG. 3. Comb of termite nest showing cauliflowers as white granules.
FIG. 4. Comb of termite nest, cauliflowers visible on upper left-hand corner.
FIG. 5. Small comb of termite seen from above.
FIG. 6. Combs of termite with fruiting body of *Agaracineae* growing from it. Excavation on side hill.
FIG. 7. Bit of comb of termite with *Agaracineae* growing from it.
FIG. 8. Comb of termite excavated to show *Agaracineae* growing from it.

Photos. by Dr. David Fairchild, Agricultural Explorer.

Plate 2

SEX

Fig. 1. *Reticulitermes flavipes* Kol. Mature egg-laying female or queen of the first form with abdomen distended as a result of post-adult growth.

Fig. 2. *Reticulitermes flavipes* Kol. Mature male with abdomen only slightly distended as a result of lesser post-adult growth.

Fig. 3. *Reticulitermes tibialis* Banks. Mature egg-laying brachypterous female or queen of the second form with abdomen distended as a result of post-adult growth.

Fig. 4. *Reticulitermes tibialis* Banks. Mature brachypterous male with abdomen only slightly distended as a result of post-adult growth.

Fig. 5. *Termopsis angusticollis* Hagen. Mature female or queen of the first form with but slightly distended abdomen due to post-adult growth. This queen is active.

Fig. 6. *Lacessitermes atrior* Holmgren. Remarkable apterous or ergatoid reproductive form from Java.

Fig. 7. *Lacessitermes atrior* Holmgren. View of head showing mandibles, compound eyes and frontal gland.

Fig. 8. *Lacessitermes atrior* Holmgren. Enlarged view of mandibles.

Fig. 9. *Lacessitermes atrior* Holmgren. Nymph of the first form with wing pads which resembles a Jassid.

Fig. 10. *Lacessitermes atrior* Holmgren. Greatly enlarged view of head of nymph showing mandibles, eyes and frontal gland.

Plate 3

FEAR

Fig. 1. *Kalotermes occidentis* Walker. Soldier showing well-developed mandibles and wing pads.

Fig. 2. *Tenuirostritermes briciae* Snyder. Nasutus with nasus or beak from which a defensive secretion is exuded; the mandibles are vestigial.

Fig. 3. *Armitermes intermedius* Snyder. Soldier with both biting mandibles and nasus.

Fig. 4. *Rhinotermes manni* Snyder. Soldier, small type with labrum extended into an elongate, slender tube "gabelnasutus."

Fig. 5. *Orthognathotermes wheeleri* Snyder. Soldier with mandibles bowed and not adapted for biting.

Fig. 6. *Neocapritermes hopkinsi* Snyder. With markedly asymmetrical mandibles.

Fig. 7. *Anoplotermes fumosus* Hagen. Winged adult—head showing well-developed mandibles.

Fig. 8. *Leucotermes tenuis* Hagen. Carton, earth-like shelter tubes, view to show how sometimes these tunnels project into space, forming branching structures. The workers were seen frequently in the openings at the ends of these tunnels, building them up further; taken in the tunnel below the spillway at Mira Flores, 70 feet below the surface; the white part is the concrete ceiling of the tunnel; taken with a flashlight by J. Zetek. Panama.

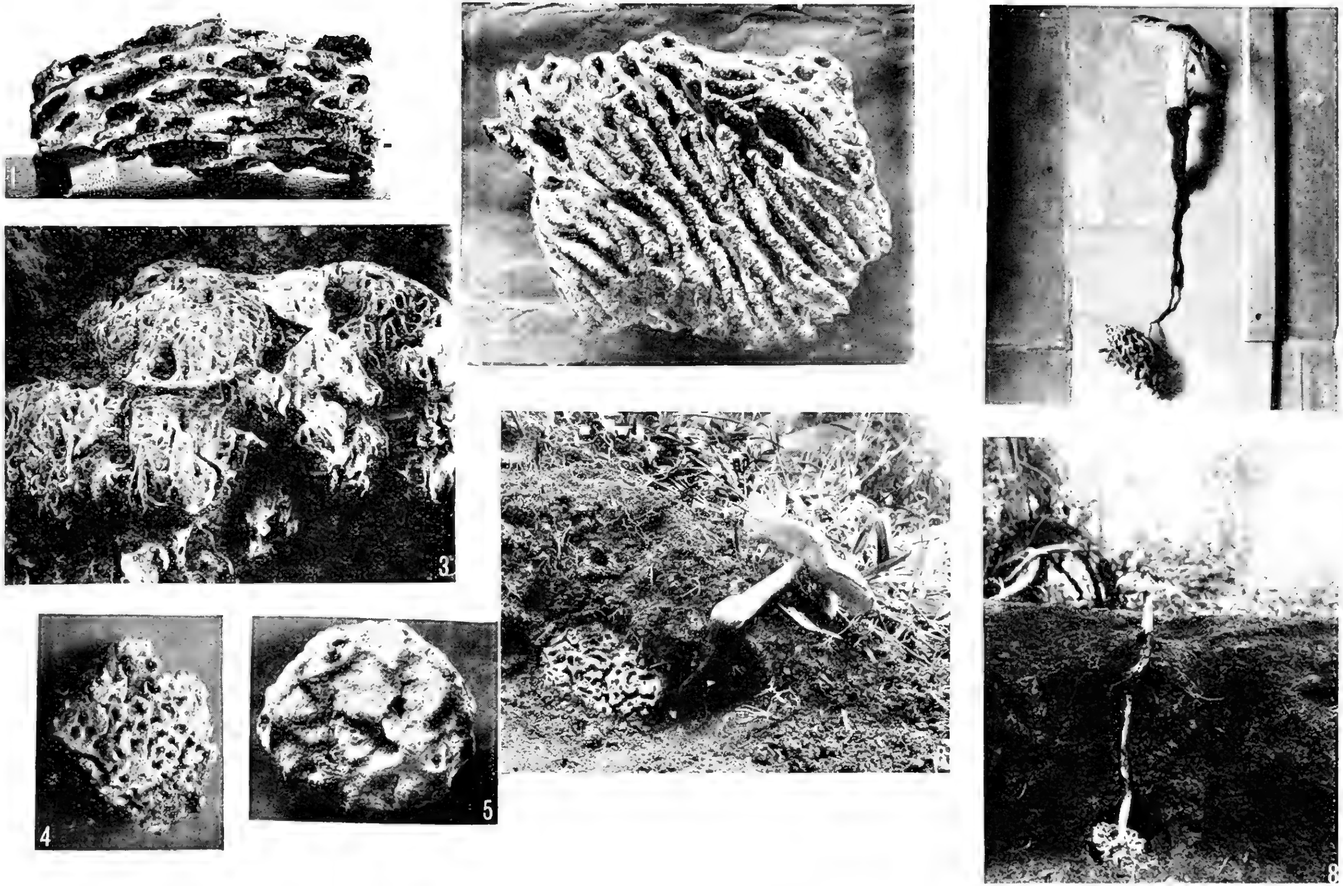
Fig. 9. *Amitermes medius* Banks. Mound termitarium on ground, several feet high. Panama.

Fig. 10. *Cryptotermes thompsonae* Snyder. Exit holes of a wood boring beetle (*Neoclytus*) in the bark on trunk of an orange tree covered over or capped by this termite by means of its impressed pellets of excrement stuck together. Panama. (View of outer bark.)

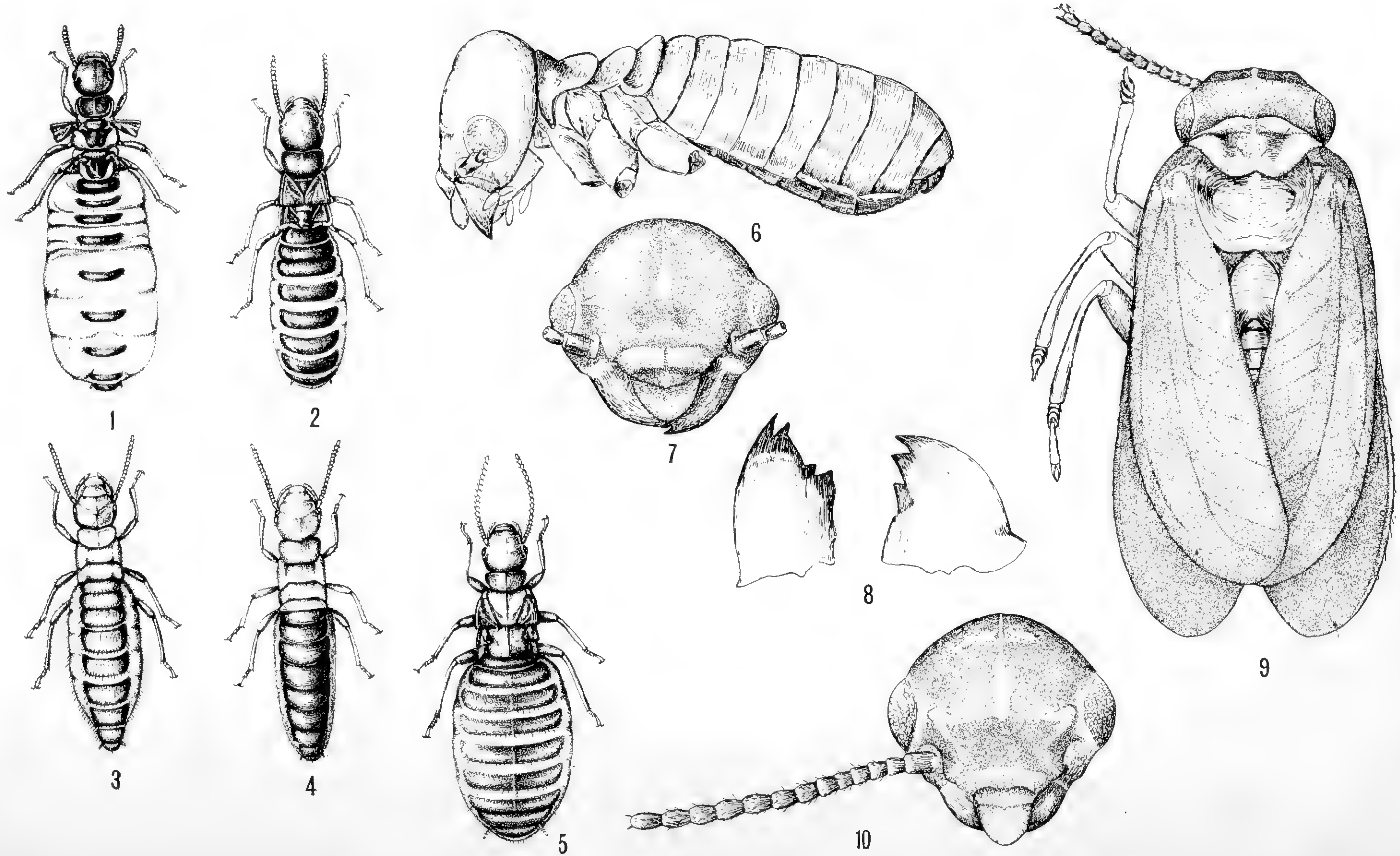
Fig. 11. *Cryptotermes thompsonae* Snyder. (View of inner bark.)

Fig. 12. *Nasutitermes cornigera* Motsch. Carton, semi-spherical tree nest. Panama.

Fig. 13. *Anoplotermes parvus* Snyder. Low, turret-like termitarium of soft, black, earth-like substance built on ground at base of tree. Panama.



HUNGER. TERMES GROUP. JAVA.



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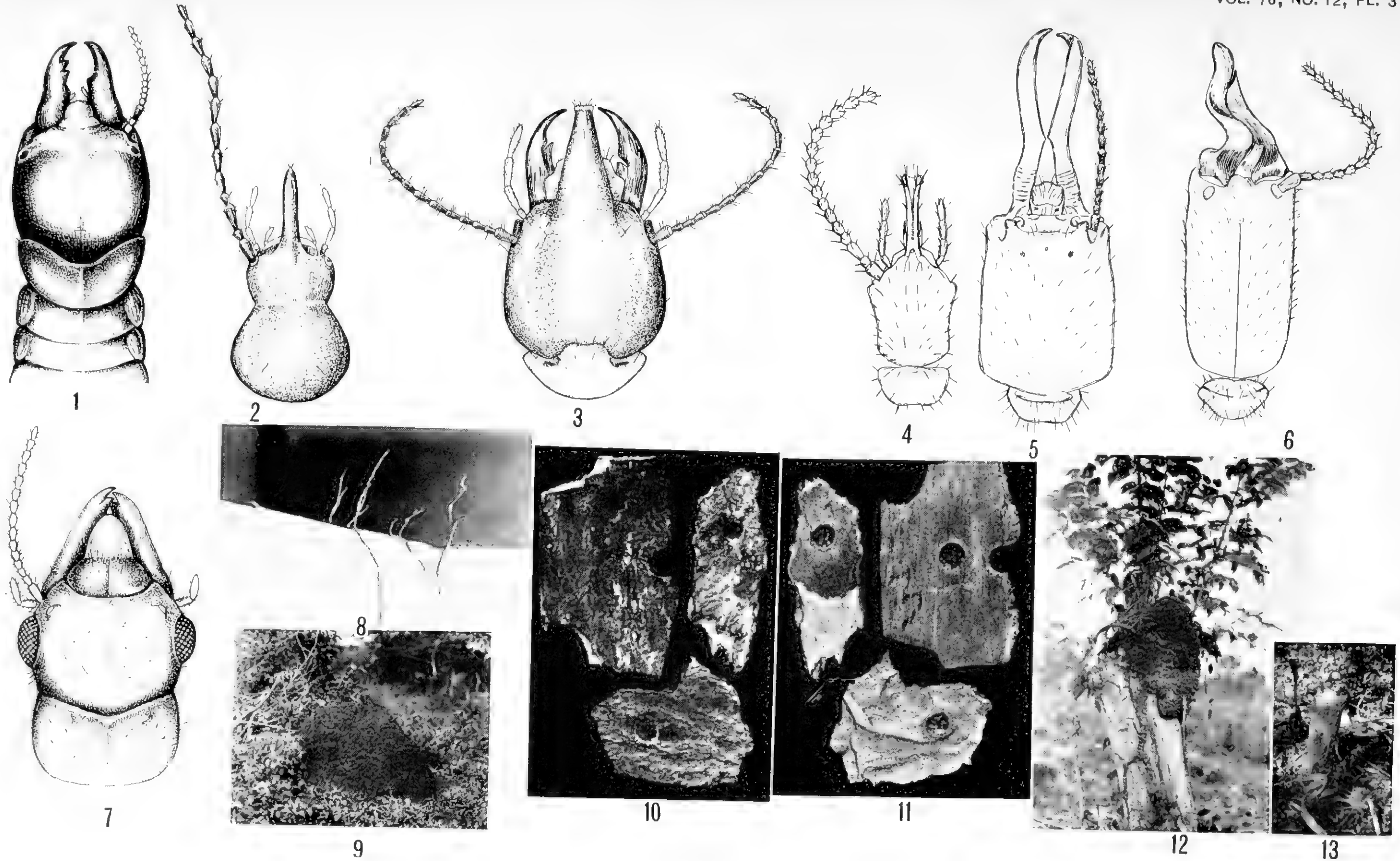

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SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 76, NUMBER 13

PRELIMINARY ARCHEOLOGICAL EXPLORATIONS AT WEEDEN ISLAND, FLORIDA

(WITH 21 PLATES)

BY
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Chief, Bureau of American Ethnology

(PUBLICATION 2787)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
OCTOBER 14, 1924

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

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INTRODUCTION

The first printed account of any considerable size of the prehistoric shell and earth mounds near St. Petersburg, Florida, known to the author, was written by Mr. S. W. Walker and published in the Smithsonian Report for 1879.[1] This account considers many shell heaps situated on Hillsborough and Tampa bays, as well as others some distance along the west shore of Florida. Of the many prehistoric mounds that formerly stood on the site of the present city of St. Petersburg, only one (pl. 1, fig. 1) remains intact at the present time. Fortunately this ancient monument was saved from vandals and occupies a conspicuous position in Hospital Park, but the others, including six of considerable magnitude, have shared the fate of many other Floridian mounds. The great majority have been carried off and used in the construction of roads in the city, for the shells of which they are composed have a commercial value for that purpose. The Bull Frog Creek Mound, one of the most extensive in 1879, is now (1924) entirely obliterated.

In his studies of Florida shell heaps, Mr. Walker made excavations in some of those on Tampa Bay, where there were several mounds of size, and prepared a map illustrating their distribution. His articles on shell heaps appear to be the most important yet published on that region. Among these the mounds at Papy's Bayou, which are near, perhaps identical with those on Weeden Island, the subject of this paper, are thus described by him:

> These mounds are situated on a narrow peninsula on the north side of Papy's Bayou, on Old Tampa Bay. The place is known as Pillan's Hummock, and has been settled at some time in the past, but I presume the settlers fled before invading hordes of mosquitoes and sand flies. A few tumble down houses in a small clearing, surrounded by straggling orange and lemon trees, will serve

[1] Mr. Walker published several papers on Florida, among which are two articles dealing with antiquities of Tampa Bay; one entitled "Preliminary Explorations Among the Indian Mounds in Southern Florida" and another, "Report on the Shell Heaps of Tampa Bay, Florida."

as a starting point to any one seeking the mound. From these "improvements" a due north course will bring one into the neighborhood of this rather singular structure.

It is an oval-shaped mound, about 5 feet high, situated in a very dense hummock. For 100 feet a ditch 2 feet deep runs in the direction of its longer diameter. At this point the structure forks, and two embankments 5 feet high continue for 50 feet, making the entire length of the mound 150 feet. The shorter diameter is 75 feet in the center, and at the southern end is 60 feet wide. The central trench is 15 feet in width, and from the southern end traces of a ditch or ancient road may be followed several hundred yards into the hummock. The embankments forming the forks are 20 feet wide when they leave the main structure, gradually narrowing down to 10 feet at the end. Figure 1, plate VI, represents a ground plan of the mound, *A* being the central depression, and *B, B,* the higher portions. *C* represents the trail or roadway leading to the mound. Figure 2 is a section across the end looking down the ditch.

Excavations revealed human bones in every portion of the mound, but by far the larger part occupied the central trench. They were in a bad state of preservation, and I succeeded in getting out only three sufficiently sound to bear transportation, after thorough saturation with boiled oil. I also found one whole bowl, but on my taking it out the bottom crumbled into powder, and the rim broke into several pieces; enough was preserved, however, to make restoration possible.

The mode of burial was precisely the same as that described minutely in the history of the Ormond Mound, and represented in figure 2, plate III, which renders repetition unnecessary. The growth on the mound consisted of small oaks, and was precisely similar to that around it. It lay with its longer diameter toward the north. Three or four hundred yards west of this is another mound, composed of alternate layers of sand and shell, 150 feet in length, by 45 in width, lying in the same direction as the other. It differs from other mounds of this class in sloping gradually from the southern to the northern end. No doubt the northern end was once level and contained a dwelling. At the highest point it is about 4½ feet above the level of the earth. Excavations have brought nothing to light worthy of note.

Great changes have occurred in this region since Mr. Walker wrote the above lines, judging from the present appearance of the mounds on Papy's Bayou and Weeden Island. Time has considerably modified the general physical features of the locality, so that it is now difficult to identify the mounds described by Mr. Walker. Their extension has been diminished and their height and configuration greatly modified. Still the above description applies in a general way to the typical mounds on the island north of Papy's Bayou (fig. 1).

The late surveys show that many shell heaps have been destroyed in the last half century; one of these on the island near the entrance to Papy's Bayou was carried away last winter. Among those that now remain is an extensive group situated on an island north of this bay, now known as Weeden Island from an old settler who lived upon it many years. Dr. Weeden planted many trees in available places and harvested good crops of citrus fruits on tracts of land that formerly were low shell heaps. He was also interested in the Indian mounds, and made a small collection of objects while living on his property, which is now (1924) installed in the Tampa Chamber of Commerce. His lifelong interest in the island and its aboriginal inhabitants is known to local archeologists and historians. He recog-

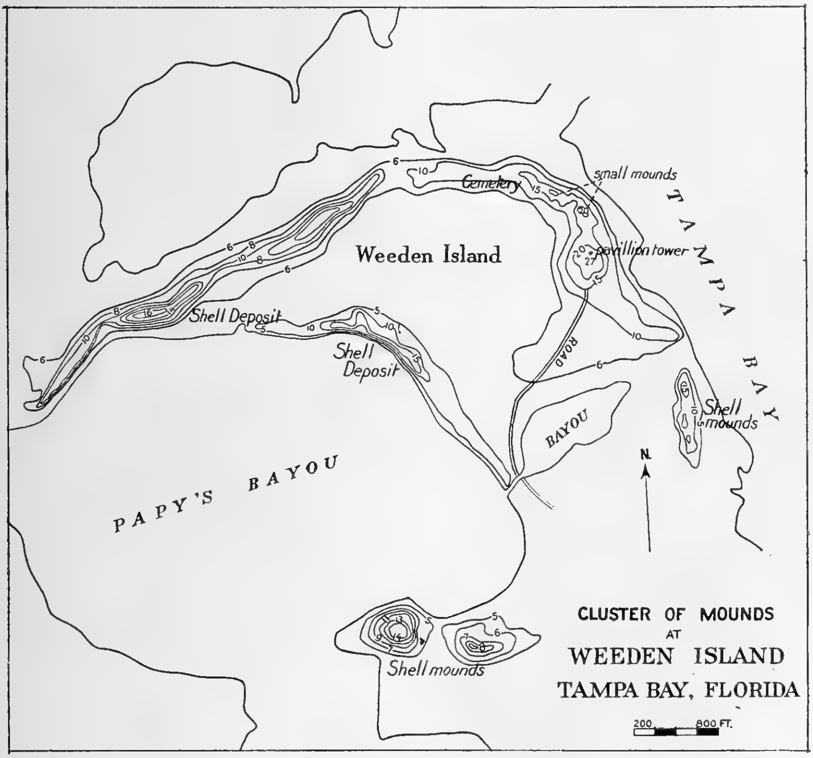

FIG. 1.

nized the great possibilities of his island as a recreation place and made an application to the United States government to have it reserved as a National Park. Dr. Weeden's homestead, which stood on the site of the present café and tower, was torn down in December, 1923. Many of the citrus trees were probably planted before his time, for it is not unusual in Florida to find a grove of lime and orange trees in an uninhabited place or on a deserted farm.

Weeden Island (fig. 1) is now owned by the Boulevard and Bay Land Development Company, under Mr. E. M. Elliott and associates.

The mounds of this island (pl. 2, fig. 1) are still conspicuous notwithstanding all are more or less worn down and one or two of them have disappeared the past winter. This island is now undergoing development as a business proposition by the company above mentioned and its appearance will be much changed in the next decade, but the intention is to preserve the mounds. On the highest point, where formerly stood Dr. Weeden's residence and out-buildings, was a large shell heap, upon which now rises a tall tower built in 1923-24. Not far away where a year ago was a jungle of palmetto and other semi-tropical plants and trees are several smaller mounds now on a park called Narvaez Park in honor of the Spanish explorer whose ill-fated expedition was lost in this neighborhood several centuries ago.

Up to the past year no extensive archeological excavations had been made on the island, although Dr. Weeden gathered a small collection of Indian surface relics, consisting mostly of shell objects, stone implements, and fragments of pottery, decorated and plain, of various kinds. No archeologist had yet put a spade into the mound excavated by the author previous to his work and its archeological treasures had not only not been revealed, but were not even suspected.[1]

The author's attention was first called to the Weeden mounds by Mr. E. M. Elliott, of St. Petersburg, who, aided by many associates, is developing the property. Mr. Elliott visited the Bureau of American Ethnology about the close of the summer of 1922 and not only invited the author to visit his island and examine these mounds, but also urged a scientific exploration in this locality by the Smithsonian Institution. It was, as may readily be seen, a great pleasure to accept this kind invitation, and in November, 1923, as Mr. Elliott's guest, a delightful trip, but all too limited in time, was made to St. Petersburg for that purpose. This visit was little more than a brief reconnaissance, but included a very profitable trip with Mr. Elliott in the yacht Sunbeam III along the Ten Thousand Islands and southwestern Florida.[2] The yacht made short stops at Charlotte Harbor, Caxambas, Marco, Horr's Island, Porpoise Point, and other places in southwestern Florida. This trip demonstrated the splendid opportunities that await the archeologist in southwest Florida.[3] For this and many

[1] With the exception of a few newspaper notices the literature of Weeden Mound is very scanty. It does not seem to have been visited by Mr. Moore's parties.

[2] The scientific results of this trip will be considered in another article.

[3] In 1918, Dr. Ales Hrdlicka, of the U. S. National Museum, visited this region for the Bureau of American Ethnology, and the results of his trip are embodied in a memoir on "The Anthropology of Florida," published by the Florida State Historical Society, No. 1, 1922.

other opportunities to carry on archeological work in Florida the author desires here to express his thanks to Mr. Elliott, who first called his attention to the mounds.

The author began his work on Weeden Island in November, 1923, by running a trench into the large shell heap on which the pavilion now stands. While this work was in progress it was necessary for him to return to Washington, and during his absence Mr. Stanley Hedberg was put in temporary charge. Later the author appointed Mr. M. W. Stirling, at that time assistant curator of the division of ethnology, U. S. National Museum, to represent him until his return to St. Petersburg, in March. The progress made in the work during his absence was very gratifying. Mr. Stirling severed his connection with the Smithsonian Institution March 15, 1924, but the author remained in St. Petersburg until the middle of April, when he packed about half of the collection and returned to Washington.[1]

The excavations at Weeden Island were carried on at the height of the tourist season and attracted wide attention not only from visitors but permanent residents throughout the State of Florida. As fast as specimens were taken out of the ground they were placed on exhibition in St. Petersburg to be examined by visitors. Frequent lectures and talks were given on them.

The work on Weeden Island was mostly confined to a single mound which for reasons that will appear may be called the cemetery (pl. 2, fig. 1). Several trial pits were made in different mounds in order to determine their nature and the work began at the mound where Dr. Weeden's house formerly stood. The first attempts were placed under the supervision of Mr. Stanley Hedberg, who with a few workmen ran a broad ditch from the north periphery to the center of this mound. Although the work was rapidly pushed with all possible care the results were few and desultory. The mound proved to be only a large shell heap with stratification of shells and sand. Few artifacts were found in it, although a great quantity of earth was removed.

This mound is evidently a place where the prehistoric inhabitants brought their molluscan food gathered in the neighboring bays and, after eating the soft animal parts, threw away the shells, thus without any design on their part inadvertently accumulating a large mound of shells. It was presumably an eating place and might be called a *kitchen midden*. Possibly it also served other purposes, as an elevated site, high above tides, for cabins, or as an observatory; but if the

[1] The aid rendered by Mr. Stirling, Mr. Hedberg, Mr. Reichard and others contributed greatly to the success of the work at Weeden Island and the author desires in this place to express his thanks to these gentlemen and others who have assisted him in the undertaking.

natives ever built houses on it these constructions had long ago disappeared. From its nature one could not expect from this mound a collection of size.

The smaller mounds west of the largest were also tested by trial holes but they gave no better promise of a collection. These mounds were small and their shape can be readily traced by their contours. Some of them seemed to be composed wholly of shells, others of earth, and still others of both, combined and stratified. No extensive excavations were undertaken on any of these, but they were left for future work after several trial pits had been made. There was one low mound some distance from the main cluster which belongs to the same group but is somewhat exceptional. A trench (pl. 4, *A-D*) in it revealed fragments of human crania, skeletons, and shards. These were good evidences of a cemetery and the work on it continued until over a third of the mound had been opened. The more the excavations were continued the more the evidences increased and supported the first impression that this was a cemetery of the prehistoric inhabitants of Weeden Island and a promising mound to open.

It is doubtful whether the mounds at Weeden Island were as densely forested in prehistoric times as at present (pl. 3). Some of the trees that now grow on them are only a few years old, but there is a huge live oak in the midst of the cluster that may have sprouted four or five centuries ago. At present, palmettos (*Sabal palmetto*), generally encumbered with Spanish moss (*Tillandsia usneoides*) and other parasites, the Saw Palmetto (*Serenoa serrulata*), the pine and other trees occur everywhere on the island and in places their abundance warrants the term jungles. The mangrove is ubiquitous, especially at the water's edge.

One of the interesting features in the key landscape near Weeden Island is the presence of so-called pseudo-atolls.[1] The cause which gave these islands their characteristic form is not definitely known although several theories have been suggested. Judged from its general form (fig. 1), it would appear that Weeden Island itself is a matured pseudo-atoll.

An important food supply of the aborigines and one that profoundly affected the culture of the ancient inhabitants on Weeden Island were the banks of shellfish providing an abundance of molluscan food in the neighboring bayous and keys. This animal, almost inexhaustible along the Florida coast, was the main food of the Indians. In shallow water near Weeden Island there are many

[1] A very good example of pseudo-atoll is found in Moreno Bay, Jamaica.

molluscan banks and there is every reason to believe that when this island was inhabited these banks were ample to furnish a food supply for many people. Moreover, the shells were the material out of which many of the implements were made. The magnitude of the shell heaps indicates a large population.

Mollusks were not the only food of the natives. They also ate fishes, birds, and other game, and no doubt eked out a slender dietary with roots and fruit. There are indications that their culture was not as low as this might imply; certainly the artifacts from Weeden Island show a higher development. Then, too, there is very good ground to believe that, even in the earliest stages, when pottery was crude, they had elaborate canoes and wooden objects. To make these demanded proficiency in wood carving, and the objects found by Cushing at Marco are instructive in this line.

There is no evidence that all the inhabitants of the villages around Tampa Bay in prehistoric times were fish or corn eaters, although it appears that the inhabitants of Florida north of Tampa used roots for food. Apparently the people that lived south of Tampa were root eaters, and, sparingly, used corn or maize. This is important, if true, for in so far as food determines a culture area, southern Florida would belong to the Antillean rather than to the southeastern culture area of the United States. The character of food alone, however, is not a good index of a culture area and it does not follow that shellfish eaters belong to the same culture area, otherwise the prehistoric people of Maine and those of southwestern Florida would be kindred. All indications show that maize was introduced as a food from the north, and the most ancient inhabitants of both coasts of southern Florida may have been ignorant of corn.

TYPES OF MOUNDS OF THE WEEDEN ISLAND VILLAGE

The Indian mounds in Florida should be studied as clusters composed of different kinds of mounds forming units, or in other words a unit is a village that includes more than one type of mounds, each for different purposes. There were mounds where food was cooked and eaten, kitchen middens formed of refuse from feasts, also mounds that served as foundations for habitations, one of which was a temple or house of the chief, and there were burial mounds or cemeteries. Each had its distinct structural type indicative in a way of its function.

Among the many mounds on Weeden Island these several types are evident. Four types were differentiated in the course of the preliminary examination. These types differ in shape, size, and structure, and were apparently used for different purposes. Their contents were first determined by shallow test holes and several of these mounds were found to be composed wholly of shells. Trial pits dug into these revealed that this type was composed of refuse mollusk shells, mainly oysters, clams, and conchs. These mounds were refuse heaps and were once used as eating places. Their contents are the unintentioned rejects of the cast-off hard parts of the food animals.[1] Mounds of this type vary in size and shape, probably resulting from the way they were made. It is probable, for instance, that they served various purposes, one of which might have been elevations from which to observe the coming and going of canoes containing either friends or enemies. Mounds of this type are often stratified. Their stratification is uneven, and they are unsymmetrical.

They yield very little of cultural import as artifacts are rarely found in them, and ordinarily they are destitute of human skeletons. Few whole pieces of pottery occur in shell deposits of this nature; the archeologist finds in them such broken fragments of implements or utensils as would naturally be dropped and lost in them by those who were using the mounds. The largest of this type of mound at Weeden Island was examined superficially and excavations made from top to base by means of a trench dug in it from periphery to center. This whole mound had the appearance of a central elevation surrounded by a raised wall, which latter, upon examination, proved to be formed by shells mixed with a very small quantity of sand. The periphery of a mound of this type is difficult to determine, since the top is worn down by erosion. The largest mounds of this type have been leveled on one slope in order to plant a grove of citrus trees, which thrive on soil of shell heaps, probably on account of the decayed organic matter formed by the remains of the feasts. Upon the surface of these shell heaps there is ordinarily a very thin layer of blown sand in which grow small trees or bushes. The appearance of the largest Weeden shell heap would not indicate, in itself, a very great antiquity, but the extension of the mound over a large area and its height implies a considerable population.

No artifacts were found in the wide trench dug into the main Weeden mound from circumference to center, although fragments of pottery and of bones of various genera of animals were scattered throughout the mound. A good supply of fresh water is situated at the periphery of this mound, and is now used as a well.

[1] On account of the haphazard way in which these eating mounds were formed and the action of the elements enlarging their peripheries, charts of their outlines are not very valuable.

Another type of mound occurring in the Weeden Island cluster structurally belongs to a second type classified as domiciliary mounds. This type shows indications of being used as the sites of houses, which were frail structures made of a framework of upright logs to which were tied sticks for the sides, the roof being thatched with palmetto leaves, and the whole building raised a few feet above the surface of the ground. The number of these mounds was not determined, as they are situated so close together that they merge into each other, indicating a settlement of considerable size and a large population. They are now covered with trees and other vegetation. Trial pits showed the existence of shells in profusion, organic matter, and a few artifacts, but extensive excavations are necessary to reveal their true nature.

To give the reader an idea of the probable appearance of a Tampa Bay village in 1540, the author cannot do better than to quote the description of a settlement called Ucita by the Gentleman of Elvas, a contemporary of De Soto. This village is known to have been situated on the shore of Tampa Bay and its site may have been that of the Weeden Island mounds. He writes as follows:

On the 25th of the month [of May, 1539], being the festival of Espiritu Santo, the land was seen, and anchor cast a league from shore, because of the shoals. On Friday, the 30th, the army landed in Florida, two leagues from the town of an Indian chief named Ucita. Two hundred and thirteen horses were set on shore, to unburden the ships, that they should draw the less water; the seamen only remained on board, who going up every day a little with the tide, the end of eight days brought them near to the town.

So soon as the people were come to land, the camp was pitched on the sea-side, nigh the bay, which goes up close to the town. . . . . At night the Governor, with a hundred men in the pinnaces, came upon a deserted town; for, so soon as the Christians appeared in sight of land, they were descried, and all along on the coast many smokes were seen to rise, which the Indians make to warn one another. The next day Luis de Moscoso, Master of the Camp, set the men in order. The horsemen he put in three squadrons—the vanguard, battalion, and rearward; and thus they marched that day and the next compassing great creeks which run up from the bay; and on the first of June, being Trinity Sunday, they arrived at the town of Ucita, where the Governor tarried.

The town was of seven or eight houses, built of timber and covered with palm-leaves. The Chief's house stood near the beach, upon a very high mount made by hand for defence; at the other end of the town was a temple, on the top of which perched a wooden fowl with gilded eyes, and within were found some pearls of small value, injured by fire, such as the Indians pierce for beads, much esteeming them, and string to wear about the neck and wrists. The Governor lodged in the house of the Chief, and with him Vasco Porcallo and Luis de Moscoso; in other houses, midway in the town, was lodged the Chief Castellan, Baltasar de Gallegos, where were set apart the provisions brought in the vessels. The rest of the dwellings, with the temple, were thrown down, and every mess of three or four soldiers made a cabin, wherein they lodged. The ground about was very fenny, and encumbered with dense thicket and high trees. The Governor ordered the woods to be felled the distance of a crossbow-shot around the place, that the horses might run, and the Christians have the advantage, should the Indians make an attack at night.[1]

The third type of building in a prehistoric Florida settlement is readily distinguished from those on the other mounds. Like the others it has no stone walls or permanent indication of the same. Its foundation is not as distinctive but is smaller than the kitchen middens already mentioned above. It is called in the above description the Chief's House or Temple.

The fourth type is distinguished by its contents. This is the place where the remains of the dead were buried, the cemetery, a low mound of sand and refuse covered with trees and bushes of various kinds, rising hardly more than four feet above the general surface of the ground, approximately circular in form. A preliminary shallow trial pit dug on one side of this mound revealed the existence of Indian bones mingled with pottery fragments in such abundance that as the work progressed these trial pits were enlarged, extending wholly across the mound. This type was the main scene of the excavations and a little more than one-third of the mound (pl. 5, *A-D*) was opened and the earth from the surface to base removed, preserving all the objects that were found from day to day.

The author's belief is that the foundation of this mound was a low hill or sand dune formed by blown coral sand in which the aborigines with their primitive implements could easily make a grave. No stones of any kind interfered with the excavations; the knoll or dune chosen for a cemetery was apparently not unlike hundreds of others along the west coast of Florida. The cemetery was inconspicuous when work began and is probably one of many that will be later discovered.

STRATIFICATION OF WEEDEN CEMETERY

Three layers, irregular in thickness, often lacking definite lines of separation, can be differentiated in Weeden Mound, but two of these

[1] The village as well as the chief was called Ucita. The site of this village has been variously determined. The majority of authors place Ucita (town) on Tampa Bay, near the present city of Tampa. The author has been greatly aided in his historical studies of southern Florida by Dr. J. R. Swanton, Ethnologist of the Bureau of American Ethnology. (See Bull. 73, Bur. Am. Ethn.)

are very evident, situated stratigraphically one above the other and distinguished by the nature of their contents. The third or uppermost is naturally modern or deposited since the locality was abandoned for burial purposes. It is penetrated by roots of trees and gives every sign of having been formed by blown sand, and reveals nothing of Indian manufacture; in other words, it seems to have been formed after the Indians had ceased to use this mound for a cemetery. Its depth averages about four inches and is fairly continuous over the mound so far as it has been excavated. Immediately below this superficial modern deposit came the first of two strata which are supposed to indicate two successive occupations. The shallowest burial (pl. 5, *C*) in this stratum was little more than four inches below the surface. At the time the mound was abandoned this skull must have been laid upon the surface of the ground or projected out of it; the modern layer had not yet formed. Down to the depth of three feet (*A, B*) we have at all intervals numerous fine examples of crania. Skulls and skeletons occur in numbers until we reach the lower portion of this stratum. The skeletons found through this layer were in bunches or bundles hastily deposited in their graves and destitute of a covering of any kind. The upright appearance (pl. 5, *D*) of long bones in the surface burials as they were uncovered led more than one visitor to exclaim, "Why, they were buried standing up!" This appearance was brought about by projecting ends of thigh bones and the skull being wrapped in large bones and the whole deposited vertically in the grave.[1] The main portion of both layers was of course formed by the blown sand, decaying refuse, and other organic matter.

Apparently a considerable time elapsed between the use of this place as a cemetery in the interval between the deposit of the lower stratum and the next in order. This is shown in places by black deposits of vegetable matter. The pottery of this layer is as a rule finely decorated and better made than that of the layer below. The implements and pottery[2] especially indicate a relationship with those people that in prehistoric times lived in the northern area of Florida and southern Georgia.

The lowest of the three deposits (pl. 7, *B, C, D*) in the Weeden Mound contains objects which belonged to an ancient people in

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[1] The method adopted to free the bones from muscles is known and both West Indians and some Florida tribes deprived the corpse of flesh before interment. (See Bushnell, Bull. 71, Bur. Amer. Ethn., pp. 95, 97. The skulls were painted vermillion, according to Romans.)

[2] See Clarence B. Moore's account of antiquities of this region.

Florida and the question who these people were is difficult to answer. It will be later discussed but provisionally it may be said that Florida was considered an island by the inhabitants of the Bahamas, to which they applied the name Cautio. We may call its inhabitants the Cautians. The author regards the Ciboney of Cuba and the Lucayans of Bahama as directly related to them culturally. We know they visited each other, which implies a close kinship.[1] The Ciboney or original people of Cuba and the Lucayans were a shell-heap people. Both were very little acquainted with pottery making, but had a few ornaments of shell. In many respects they were retarded in their cultural development and in about the same condition as the Cautians whose remains occur in Florida in this lower layer.

In other words, it is believed that there were two waves of immigrants into Florida in prehistoric times; one from the north, which brought with it the articles akin to those of Georgia, illustrated in the upper layer of the cemetery at Weeden Island, and another like those of the West Indies, corresponding to the lower layer, which were submerged by an influx of the northern clans, whose origin is yet wholly unknown. It is supposed that the archaic population of Florida was practically identical with the earliest people of Cuba, and in order to determine whether there was any difference in the crania of the peoples in the two layers of the stratification, the author had prepared a map, the numbers on which, reaching 444 entries, correspond with skulls and bones which were found at different depths. It is hoped that an examination by some anthropologist will aid in the deciphering of this problem. A few facts regarding the collection of somatological material may be instructive but a determination of racial relations is not attempted.

HUMAN BURIALS

The majority of human burials in the Weeden Mound were secondary, or those in which the skeletons had been stripped of flesh, done up in bundles, and later interred in that condition. There were instances of extended and flexed interments but in the majority of cases the smaller bones were not present; the larger bones of the arms, legs, and sometimes vertebræ, were bunched together. There were several instances where only the skull (pl. 7, *A*) was found and in others the bones of the arms and legs alone remain. These bones were commonly buried upright, not extended. They were very fragile and were preserved with considerable difficulty.

[1] An Indian village, Tergesta, once stood on about the same site as Miami and the interchange between it and Cuba or the Bahamas appears to have been frequent.

The burials were thickly crowded together, one above another, facing upward, downward, and laterally. There was apparently no uniformity in the position in which they were laid. Cross sections of a vertical hole excavated in the sand in which the skeleton was dropped are seen in plate 7, *D*. Above the skeleton was often placed a layer of oyster or other shells and a thin layer of sand. In some instances only sand covered the interment.

The roots of the trees growing on the mound sometimes penetrated the earth through the skull and often filled the cavities of the long bones. These roots were often so numerous that the exterior of the long bones was covered by them.

Lieut. A. W. Vogdes, of the Fifth Infantry, U. S. A., who in 1876 published an account of the Vogdes Mound near Tampa, found evidences of cannibalism in prehistoric times. The skull and bones of a dog and split tibia (possibly for marrow) of a human being also occur. Fragments of charcoal are now and then found scattered through the mound but evidences of fire pits are difficult to discover.

Diseased and broken human bones, sometimes healed or grown together, were found in the mound. There were two infant skeletons, one of a fœtus. A similar fœtus was described by Mr. Clarence B. Moore.[1] Perhaps the most exceptional interment of a baby's skeleton was the use of a large bivalve mussel shell for a coffin. One of these was found in the Weeden Mound.

The situation of many human crania found below the surface will be shown on a chart to be published later where the depth below the surface is also mentioned. The vertical wall of the trench is in some cases shown (pl. 5, *A*) with the skulls projected from the bank. As the skeletons were very fragile and easily fell into fragments if handled just after they were found, it was customary to leave them exposed to the sun and air a few days after they were found or until they hardened. This also gave visitors an opportunity to " see the remains " before they were transferred to paper " nail bags " in which they were kept, numbers being added to each bag to show the locality and depth at which they were found.

Plate 6, *A*, shows two skulls *in situ* near a hole in the bank out of which the large black bowl (pl. 21, *C*) was taken. These two skulls rest on the top of the lower layer of stratification, the bowl being probably a mortuary offering belonging to the " lower stratum."

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[1] The works of Mr. Clarence B. Moore on Florida archeology have been of greatest aid to the author in the preparation of this article and he takes this opportunity to express his appreciation of them.

In plate 5, *D,* we can also see two crania buried in a shallow grave. The upper cranium (pl. 6, *B*) is surrounded by long bones buried four inches below the surface; the lower (pl. 6, *B, C*) resting on top of the lower "stratum." The crania of both *A* and *B,* plate 7, rest on the same layer.

The relationship of the skulls of the lower layer to those of the upper stratum is shown in plate 6, *B,* and plate 7, *A,* shows a skull before it was removed from the earth. Mr. Reichard is shown wiping off the superfluous sand with a small paint brush. When first exposed each cranium has a reddish color which becomes whiter as the skull dries by exposure. When the sand clinging to it is removed it dries faster. This particular skull (pl. 7, *B*) lies on top of the lower layer, three feet below the surface. The white surface is the natural sand below the lower layer. Plate 6, *B, C, D,* shows the vertical bank with the human crania protruding from the side. The different burials on the several layers are shown and the crania indicate the level of separation of these layers.

Plate 8, *A,* shows the customary group of visitors at the excavation. They numbered several hundred daily and on Sunday over a thousand.[1] Plate 8, *C,* shows one of the few human skeletons that were found extended or with a well-preserved vertebral column.[2] Plate 8, *D,* shows leg bones that projected from the ground before excavation.

POTTERY

Three of the figures on plate 4 show the position of a capacious black food bowl in the lower layer before it was removed from the earth, and in a fourth (*B*) a workman is repairing it. Another figure (*C*) shows a boy digging out a human skeleton found near the bowl. Although this food bowl was broken into many fragments most of the parts were gathered together and a complete bowl restored. Unlike the majority of vessels found in the cemetery this specimen was not "killed," although broken into many fragments.

The decorative pottery (pls. 9 and 10) excavated at Weeden Island was mainly found reversed in the upper layer, or that immediately below the superficial layer of modern or historic time. This pottery is of the finest character and compares well with that from other areas in North America. It takes various forms, as large food bowls, platters, spherical bowls, vases, elongated jars (pl. 11), and cups. As a rule the paste of which it is made is coarse and rough,

[1] It was found necessary to rope in the trenches and not allow visitors to enter, but from the dump they had a good view of the work as it progressed.

[2] Also pl. 2, fig. 2.

sometimes tempered. Superficially it exhibits no evidences of painted decorations or symbols, although some shards are banded with red and dark brown colors. It often has a fine gloss, not glazed.

In the large number and variety of form of the vessels of burnt clay it is not strange that the uses of several types cannot be determined definitely. We miss certain forms, as ladles, cups, handled amphoras and effigy jars, but to offset these there are several varieties peculiar to Florida. Among the latter may be mentioned the cylindrical form with beautiful superficial decorations (pl. 11), square boxlike medicine bowls and thin pottery objects like frustra of cones open at base and apex (pl. 12, *E, F, G*).

Certain smaller hollow globular bowls made of clay and perforated on one side, resembling bowls of pipes, were probably used for smoking, but the globular clay pipe, although not foreign to Florida, is not found in the collection from Weeden Island.[1]

HUMAN HEADS MADE OF BURNT CLAY

Representations of four human heads of clay in low relief are found on shards. Two of these heads (pl. 10, *E, F*) are as well made as any taken from Florida mounds and were attached to the rims of bowls, facing outward. They were in relief and the bodies, legs and arms of the human being were not represented. The surface of the bowl was decorated with geometric figures. They were probably duplicated on the diametrically opposite rim of the bowl.

The human heads in relief are among the best-made prehistoric ceramic decorations of pottery and are not common in the collections made in South Florida.[2] No effigy bowls occur in the collection from Weeden Island. The bowls and vases of the upper layer were nearly all "killed," a hole being broken in the bottom of about every vessel. The edges of this perforation were sometimes smoothed over after the fracture. No specimens were found that had been manufactured and artificially punctured for mortuary purposes before they were fired. The object of the "killing" of a vessel was, of course, to let out the spirit of the vessel when buried with the dead.[3] Commonly

[1] There were two clay pipes badly broken and one almost entire in the collection.

[2] Clarence B. Moore (Notes on Ten Thousand Islands) figures (p. 463) a human head effigy from Chokoloskee Key. In the Index he refers to "human head-effigies on rim of vessel" collected at Moundsville, but makes no reference to it in text.

[3] Mr. Clarence B. Moore has called attention to this feature on Florida pottery in several articles.

the decorated vessels were placed in a reversed position, but some of them were still upright. They contained decaying organic matter, probably remains of food. There are in the collection no examples of urn burials, although in some cases a reversed food bowl fitted close upon a human skull. The many scattered fragments implies that vessels were purposely broken—a modified form of "killing"—before they were deposited with the dead. In most cases the Tampa Bay ware has geometrical decorations, but jars bearing on their rims heads of human beings, animals, or birds were rare. In one or two instances the head of a bird was represented in low relief and the accompanying avian body simply smooth without elevation. The decoration of the pottery is exceptional in that the designs are incised and generally formed by series of punctures or incised lines. The exterior, and occasionally the interior, of food bowls was decorated, but the ornamentation of jars is generally limited to their exteriors. This use of dots or punctation (punctures forming lines) is one of the distinctive features of Florida ceramics and the designs are generally conventional figures.

In a study of the various decorated fragments which the author obtained he was particularly struck with certain resemblances in method of drawing to designs found on West Indian gourds or calabashes, especially when lines are formed by a series of punctures. In West Indian pottery, especially the Tainan of Porto Rico and Santo Domingo, the lines terminate both with and without punctures. There is here figured (pl. 13, fig. 1) an ornamented Cuban calabash, the geometric lines on which recall very closely some of the decorations on the pottery from Florida. It would seem that the style of decoration of Florida pottery is a survival of that used in the decorative technique of calabashes, or that the technique of the ornamentation of gourds had been taken as a motive for the decoration of pottery.

Besides the regularly formed jars, platters, and bowls resembling those common in prehistoric southwestern ruins we find in the Florida mounds cone-shaped vessels without top or bottom, and long hollow clay cylinders adorned on the outside with decorations of unknown meaning. These elaborately decorated objects are apparently important religious paraphernalia but of unknown significance. Some of these bowls are very deep, often long and narrow, but without a base or too unstable to stand upright when placed in position. It would seem that such a vessel was intended to be carried in the hands of the participants in ceremonial processions or dances; or set in sand to afford a base or rest to keep it upright.

The author has made a considerable search for deposits of fire clay out of which the terra cotta objects of Weeden Island were made, and has not been wholly unsuccessful. There is a considerable body of marl mixed with clay but this generally becomes quicklime when submitted to heat. A fairly thick stratum of almost pure clay of excellent character was discovered by men working a steam shovel, near Papy's Bayou, which may have been the material the ancient potters used in the manufacture of their pottery.

There is no evidence, however, that the ancient potters were acquainted with the potter's wheel or that they glazed their work, but it would appear that the apparent glaze which many of the pottery objects possess was due to smooth gloss obtained with polishing stones with which the rough clay was rubbed. No glazed pottery was found in the author's excavation, and no designs were painted on the vessels.

Among the remarkable examples of unbroken pottery that were found at Weeden Island there are four specimens which from their general character and decoration are especially worthy of extended consideration. These are supposed to have been used by the aborigines of that island for ceremonial purposes, and are figured in the following plates:

Plate 9, *A, A,* represents a thick-walled bowl which, when seen from above, is oval in shape. The design, which is brought out in plate 10, *A,* is limited to the upper region of the outside of the bowl and is composed of dual units, that is, the figures on two opposite diameters, while partaking of the same general character, are slightly different in their appearance from those at right angles. It is impossible for the author to determine what these designs represent, but there is little question that there are embodied in them feathers or wings, organs of some bird, but highly conventionalized. We have, for instance, in the center a circular figure that may represent the head, from which are extensions on either side, in form conventionalized wings. The body hangs below the head. In figure *A* (right), where another quadrant is represented, the avian character, although preserving a general symbolic likeness, is somewhat different. A remarkable feature about this bowl is the existence on the rim at the ends of the shorter diameter of a small protuberance, connected along the rim itself by a punctured line. This bowl, like all the others, was perforated or "killed" before it was buried.[1]

[1] As these bowls were buried in a cache containing ten specimens their condition would indicate not that they were wholly mortuary but simply hidden by burial in the mound.

Plate 10, *B*, shows a view of the vessel (pl. 9, *B*) from above. The designs at two ends of a diameter are almost the same and bear identical decoration. This bowl recalls that just considered, with the exception that its general form is globular with an in-curved rim undecorated, and there is only one unit of decoration.

Plate 9, *C*, also represents a globular bowl, the decoration of which may be highly conventionalized figures like serpents winding about the bowl, the outlines indicated like the others by punctures. This bowl is one of the most symmetrical of all those that were found, and the design is the only one suggesting the serpent.

Plate 9, *D, D*, likewise represents a small globular bowl which has two units of decoration similar in design. It is not perfectly spherical but has knobs or mammae-like elevations at opposite ends of the longer axis. These knobs bear as unique decorations (pl. 10, *D*), conventional forms which cannot be identified. This bowl is smaller than the two just mentioned and was one of a nest of ten, six of which were broken and four entire.

Perhaps the most remarkable of all these bowls is shown in plate 11, which recalls in its general form the cylindrical ceremonial vases discovered in great numbers by Mr. G. H. Pepper in one of the rooms of the great pueblo ruin, Pueblo Bonito, in New Mexico. Although broken when found it was cleverly mended by Mr. Egbert, who cemented the decorated fragments together and restored the vessel to its original form, as shown in plate 11. This vessel may likewise have been ceremonial. It is too small for use as a food bowl, and was made and decorated with the greatest care. The portions which have been added in repairing it are plainly indicated. So far as the author has examined the collections previously made in Florida, they contain no specimen of the same general form as this, although one collected from Tarpon Springs by Mr. Cushing has a similar ornamentation.

In the next plate (pl. 12, *D*) there is represented a globular bowl but the incised figure on it is so much worn that it is difficult to decipher. Its general character is the same as that on plate 9, *B*.

We also found at Weeden Mound a few bowls of globular form (pl. 21, *E*) that are destitute of decoration, which shows that this form of vessel is not rare in the mound. These bowls were sometimes cached or thrown in a heap, and it is instructive that all were found together in the upper layer. Several simple small globular bowls[1] with very thick walls and their surfaces unadorned with a design or with paralleled incised lines (pl. 12, *B*) were likewise collected at Weeden Island. Some of these may have contained food, others for condiments. A few had encircling or vertical parallel incised lines on their outer surface and various other generally rectangular figures, all very coarse and apparently purely decorative.

Among the most remarkable ceramic objects found at Weeden Island are those jars shaped like frustra of cones open at base and apex, one of which is shown in plate 12, *E, F,* and *G*. There are several of these jars in the collection, the use of which the author is unable to determine. The decoration on the outside is crude, without tattooed designs. Few vessels of this shape have yet been recorded by students of Floridian archeology, and these forms may be peculiar to the Tampa Bay region.

There are a few larger fragments of particular interest. One of the finest animal designs (pl. 14, fig. 1) represents a bird, possibly a pelican. The fine bowl upon which it was made in relief was a ceremonial one, which may account for the care used in its production and suggests that the intention was to represent one of the sacred birds of the ancient Florida Indians. Both head and beak are in low relief, the head a circle with one eye (pl. 18, *A*). The two clavate bodies on the head represent wings or feathers. The greater part of the body that remains is indicated by punctations but an open space enclosing a picture of the heart in form of a puncture is left in the middle. This is a common way among primitive people of representing internal organs.

More or less conventional pictures that may represent various birds appear on several bowls, and it would seem that, as among the pueblo Indians, the feather was adopted by these Florida people as a decorative element and appears in many different forms.

There are only a few representations of animals on the pottery obtained at Weeden Island, one of which, with protruding eyes and serpentine body, bears a marked resemblance to a fish. The serpent itself appears not to have been represented as in northwestern Florida and Georgia.

The number of realistic figures thus far found in the decoration of Florida ceramics is small, but it would seem that there are several conventionalized designs that have thus far not been determined.

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[1] These are sometimes cubical with almost vertical sides. South of Tampa Bay, especially where clay is rarely found, these are made of hard wood, the utensils being about the same shape as those made of clay.

In one fragment we detect a remote similarity to a fish made in relief on a shard, but no other instance of even a remote likeness to an aquatic animal can be detected.

There is a great variety of stamped designs, of which the checker pattern is the most abundant. Designs of all kinds as a rule were confined to the outer surfaces of vessels but there are a few in which the decoration is on the interior. These stamped ornaments are similar to those of other parts of Florida.

PUNCTATION

The geometrical designs are punctated pyriform, spirals, ovals, circles, scrolls, and rectangular figures. Some of these are identified as feathers, but many are simply cross-hatched spirals and parallel lines.

One of the marked characters of the decorated pottery from Florida is the use of punctures in outlining designs; this method of ornamentation, as elsewhere indicated, is a survival of calabash decoration[1] (pls. 16-20).

The formation of designs on pottery by the use of superficial punctures is not a very common feature in prehistoric decoration, although it is found at various places in the Florida-Georgia area. It reached a high development at Weeden Island.

These punctures may be arranged in clusters or in straight or curved lines. Incised lines often bear serial or terminal punctures. The latter is common in Tainan pottery of Porto Rico and Santo Domingo, where the terminal puncture varies according to the shape of the point of the implement with which it was made, the triangular form predominating.

There is one form of puncture often isolated, sometimes terminal, which merits especial notice. This form is perfectly circular and smooth as if made by revolving an implement with circular point and may be designated as a circular puncture.

These different varieties of punctation may occur on the same bowl and their combination may lead to a very composite design.

STAMPED DESIGNS

There is a very great variety of stamped designs, apparently made with a wooden paddle or stamp and applied to the vessel before it was baked or while the surface was still soft and would readily receive an impression. These are so regular in form that we can

[1] A somewhat better term for this method of representing figures is "tattooing," used by Cushing in labeling photographs of pottery from Tarpon Springs, Florida.

hardly believe they were handmade but must have been mechanically applied (pl. 14, *B*).

The most common stamped designs are the checker patterns, which include square, rectangular, and diagonal, formed by different arrangement of the outlines of the stamp. Under the category of stamped designs may also be mentioned the circular, oval and other regular figures formed by curved lines, spiral to parallel. The number of these geometrical patterns is large and they seem to occupy much the same relations to the undecorative pottery and that with elaborate designs that the corrugated pottery of the pueblos does to the painted ware or that with conventional or realistic figures.

The great variety of forms of these stamped designs indicates to the author's mind a considerable infusion of elements of pottery decoration from outside and points to a northern origin. While the stamped pottery from Weeden Island is believed to be older than that with punctured designs, and possibly lies under it stratigraphically, the author is not at present able to definitely make up his mind on its sequence.[1] Thousands of fragments with stamped designs were found, including all those recorded from southeastern United States as well as the Florida peninsula.

SHELL OBJECTS FROM LOWER LAYER

The excavations made at Weeden Island revealed a considerable number of implements made of shell and a few of bone. These objects occur at all depths from the lowest to the highest, and assume a variety of forms. Perhaps the most numerous of the shell utensils were drinking cups made of conch shells, the lip being artificially smoothed and the spire formed into a handle. Drinking cups of this kind containing the "black drink" were placed upon the graves of the dead, according to early writers. These shells were used in ceremonials and are represented in certain early illustrations which represent shell drinking cups placed on a mound of earth with a group of mourners surrounding them. One of the Indians, evidently a chief, is sometimes figured drinking from a shell cup. A fairly large number of these cups was found on top of the mound at Weeden Island.

Weapons made from fossil conch shells are also represented.[2] Several celt-shaped objects of celt form but made from the lips of

[1] See Nelson's "*Chronology in Florida*," Anthrop. Papers, Amer. Mus. Nat. Hist., vol. XXII, part 2, 1918.

[2] A number of these are figured by Mr. Moore and other students.

conch shells, not stones, were discovered in the shell heap. The edges of these implements were sharpened by artificial means. The whorl of a shell was often perforated and through this hole a wooden handle was inserted. This implement became very effective, especially when semi-fossilized, and was used in the same way as the ax or hatchet made of stone. Very few stone weapons[1] were found throughout the excavation, which was to be expected since there were no stones available for that purpose. Another form of shell implement had a sharp cutting edge like a knife or war celt. It was manufactured from the lip of the conch shell, curved and sharpened at one end and pointed at the opposite extremity. This implement was evidently carried in the hand and not hafted upon a handle.

There were several other types of cutting implements made of shell, and from the same material the aborigines made needles, bodkins, beads and ornaments. Shell pendants evidently fringed their scanty kilts. Similar pendants of bone or stone were strung along the lower edge of their kilts, and served as rattles in their dances. Some authors have interpreted them as sinkers for fishing nets, but their small size and often beautiful finish belies this explanation. Not only have they been found on the garments of Indians but have also been figured in this position by artists.[2] Marine shells lend themselves to ornamentation on account of their pearly luster and the fact that they are soft and can be readily incised or worked into many different forms. Among these ornaments we have circular disks or elongated plates perforated for suspension. Some of the shells were suspended from the neck as a pectoral.

A few small beads also were found, some of considerable size. In none of the shell disks from Weeden Island was there any example of incised shells, so common in Tennessee and Georgia, although shell beads were sometimes decorated.

A remarkable cluster of sun shells (pl. 21, *D*) was found about three feet below the surface. Bone objects bound by some form of vegetable fiber, perhaps Spanish moss, were found placed in a sun shell about five inches long. Another shell served as a cover and thus it was deposited in the ground.

STONE WEIGHTS FOR NETS

The prevalent rock of Tampa Bay is a coquina, or limestone, that does not lend itself to the manufacture of finely polished stone

[1] No polished stone celts or grooved axes.

[2] Notably in White's interesting volume so frequently quoted by students of the Floridian Indians.

implements.[1] It is a modern formation, soft and very friable, a kind of coral limestone which hardens somewhat on exposure to air, but which never becomes very compact. It is of late formation; modern shells and even human bones are imbedded in it. We find repeatedly in this region not only fragments of pottery imbedded in this hardened limestone, but also various undoubted modern objects. This rock is also prehistoric in formation, and was sometimes made into weights (pl. 21, *A*, 1) for fishing nets.

A kind of rock resulting from the tubes of certain marine worms formed in compact masses also served for weights (pl. 21, *A*, 1). This rock is not very hard and is not suitable for utensils or implements. These stones were possibly attached to nets and used for sinkers, and generally have a triangular form. They are perforated through the middle and apparently attached by means of strings.

PROBLEMATICAL STONE

Among the stone objects obtained at Caxambas and presented to the author was one supposed by the donor to have been used as a primitive anchor, but the evidence indicates rather that it was used in the preparation of meal from roots. Little is known of the vegetable food of the ancient Floridians, but it is recorded that by grinding certain seeds and roots, as those of nymphaea, meal was obtained from which they made a pancake which was fried over the fire. A circular object from southwest Florida may possibly have been the nether stone of a mill upon which these seeds were ground. This object is about a foot and a half in diameter, flat on one side, rough on the other, with an eccentric hole. It was used somewhat like a quern and into this hole was inserted the stick by means of which a rotary motion was imparted to a millstone.

CONCLUSIONS

AGE OF WEEDEN CEMETERY

The objects gathered from the excavation of the burial mound at Weeden Island add nothing to our knowledge of the age of the skeletons and mortuary objects found in it, save that these objects are prehistoric, which in Florida means any date of the Christian Era earlier than the advent of the Spanish conquerors, or 1500. The natives probably never saw a white man or heard of a European,

[1] Arrow and spear points (pl. 21, *A*, 3) made of flint and occasionally a banner stone are found on the surface of Florida mounds, but these bear every evidence of modern introduction, possibly by the Seminoles.

which does not mean, however, that they were of very great antiquity, nor does it signify that some of their descendants might not have gazed with wonder on the soldiers of De Soto. It is possible, on the other hand, that the Spanish explorers saw the sons or grandsons of those who were buried in this cemetery.

No object of European manufacture has been found in the Weeden graveyard. That is significant for it indicates the white man exerted no influence on the arts of men and women buried there. Whatever we can glean from the remains shows that they were strictly American. Moreover, there is some evidence in the Weeden Mound of a considerable lapse of time between the first and the last interments and that two layers indicating distinct kinds of burial and culture may be shown by superimposition. That is important. Who were these people, how long ago did they live, and what became of their descendants? These are the perennial unanswered questions. They were Indians, that we know; but the documentary records we have of their life are insufficient to determine who they were. If any one is to find a key to their manners and customs it must be the archeologist, and we look to renewed research for this key. The author finds the following layers in the mound from the surface down: 1, Modern; 2, Upper Layer, Muskhogean; 3, Lower Layer, Cautian (Antillean).

RELATION OF CUBAN AND FLORIDIAN PREHISTORIC CULTURES

Of all artifacts collected by archeologists, pottery is among the most satisfactory in comparisons of primitive cultures. Upon it is depicted much that affords explanations of aboriginal life. It will be seen by an examination of the decorations on the upper stratum of pottery from Weeden Island that it belongs to the Georgia-Florida or rather Southeastern North American group in which figures are made by a succession of punctures. This method of making designs readily separates this from the other culture areas of North America, as will be apparent when we compare the designs of the specialized ceramic area of the peninsula of Florida and pottery of the Gulf States, Alabama, and Mississippi and other areas.

When we compare the Florida pottery with the highest decorated ceramics from the West Indies we find considerable difference between it and that of the Tainan of Cuba, Santo Domingo, and Porto Rico, where ceramic art reached its highest efflorescence, and are unable to refer it to the Antillean area. But the crude pottery of the lower stratum resembles that of the lower stratum of the West Indies.

The author has discussed in the preceding pages the more important objects excavated at the Weeden Mound in 1923-24, but a large number of additional specimens still remain in St. Petersburg awaiting their place in the final report.

Columbus on his first voyage cruised along the northern coast of Cuba and there learned of a tribe called Guanahatibibes, who lived in caves. These were the original or oldest inhabitants of Cuba. The Tainan culture of the eastern end of this island was later and exotic. Mr. M. R. Harrington has shown in his valuable contribution on "Cuba Before Columbus"[1] that the Guanahatibibes or Ciboney artifacts continue under those of the Tainan or pottery makers of the east end of the island; in other words, there is good evidence that the original population of Cuba was much more primitive in culture than the later, as the author has pointed out in his paper on the "Archaeology of Cuba." Later observations suggest that the lowest layer, or Ciboney culture above mentioned, was also represented in other West Indian shell heaps. This archaic culture distinguished by little or no ceramics has been detected in Cuba, Haiti, Porto Rico, the Lesser Antilles, and elsewhere, and when Columbus landed on the West Indies survivors of it were still represented on these islands.

There was a close likeness between the original or archaic population of Florida south of a line from the east coast to Charlotte Harbor on the west coast, and the earliest population of the West Indies; and the evidence is fairly good that the archaic culture of the Greater Antilles extended over the northern portion of the peninsula of Florida under a superficial Muskhogean or later development. The question now arises, did the lower or older culture migrate to Florida from the West Indies, or was it autochthonous both in Florida and the West Indies.

The designs used in the decoration of the pottery of the upper layer as here illustrated in Weeden Island are of wide extension northward, and the important question to consider is whether the lower layer which indicates the earliest culture is an extension of a northern people from the continent southward or a southern culture from the West Indies into the peninsula of Florida. Certain facts lead the author to associate closely the Floridian and Caribbean archaic cultures.

There is no likeness between the decorated pottery of Weeden Island and the so-called Tainan ware of the Antilles. Whatever

[1] Indian Notes and Monographs, 1921.

relationship exists between Floridian and Antillean ceramics is found in the ancient forms or those found in the lower strata. In the absence of knowledge as to the relationship of the people who inhabited the Weeden Island mounds and the Indians found on Tampa Bay by the Spaniards, we cannot say whether they were ancestors of the Caloosa or Timucuan. This determination awaits future studies.

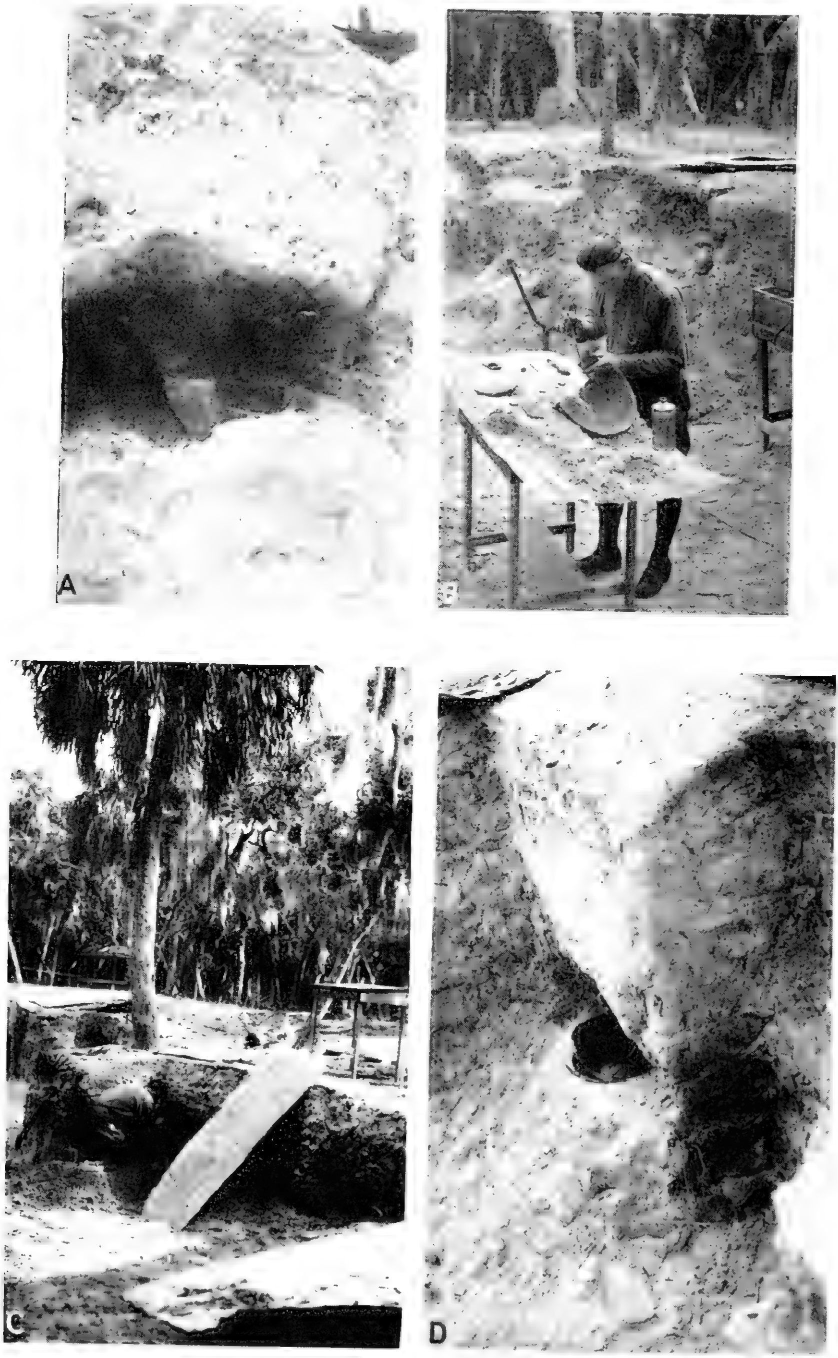
1. Oyster shell mound on hospital ground, St. Petersburg, Florida. All the covering soil has been removed and other changes made.

2. View from Weeden Mound looking about due north, over Tampa Bay, showing keys along shore. Photograph by Beck.

1. Indian mound, Weeden Island, Narvaez Park, St. Petersburg, Florida. Photograph by Beck.

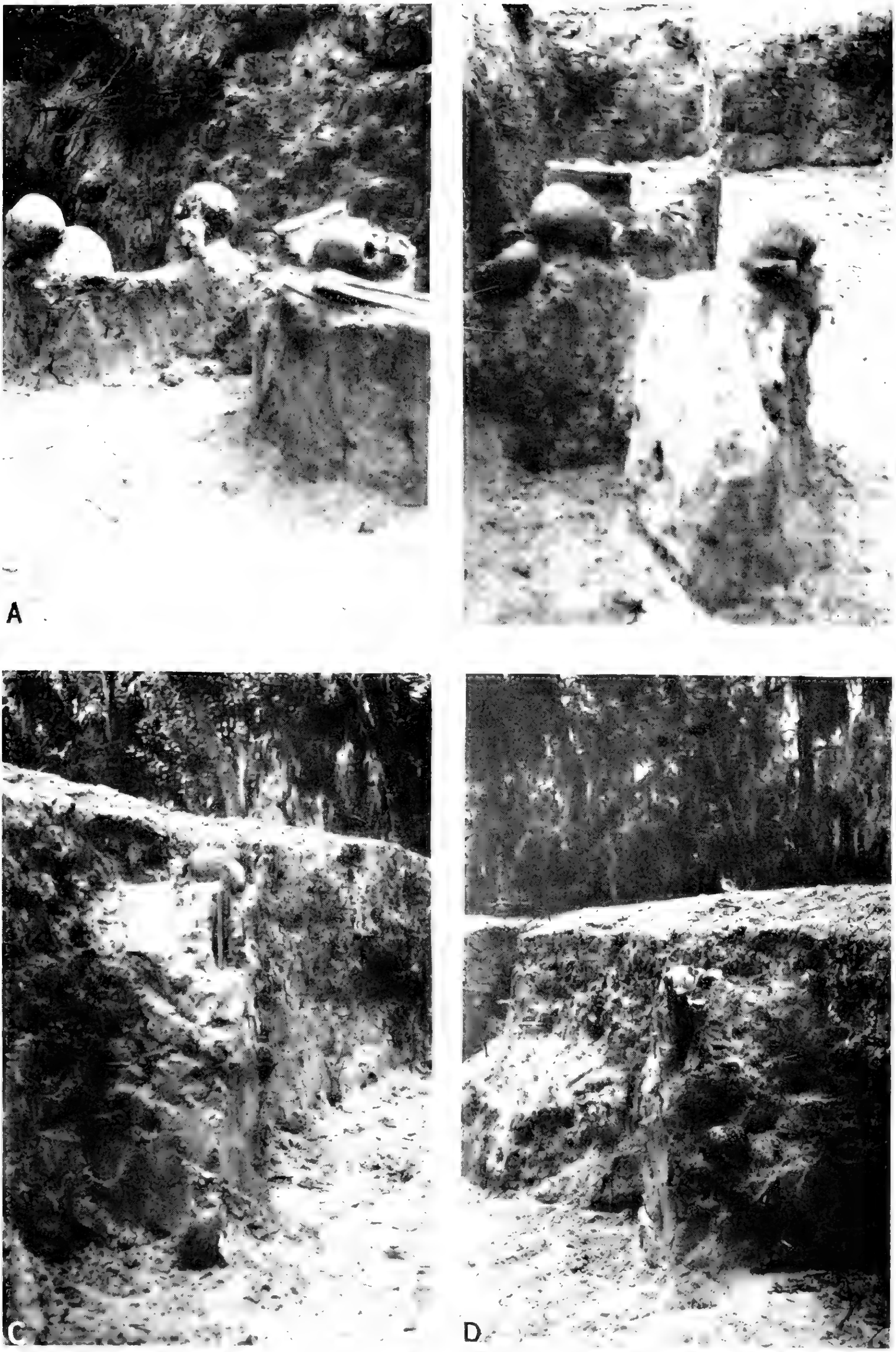
2. Flexed skeleton, Weeden Mound, St. Petersburg, Florida. Photograph by Beck.

Semitropical vegetation, Weeden Island, St. Petersburg, Florida. Photograph by Beck.



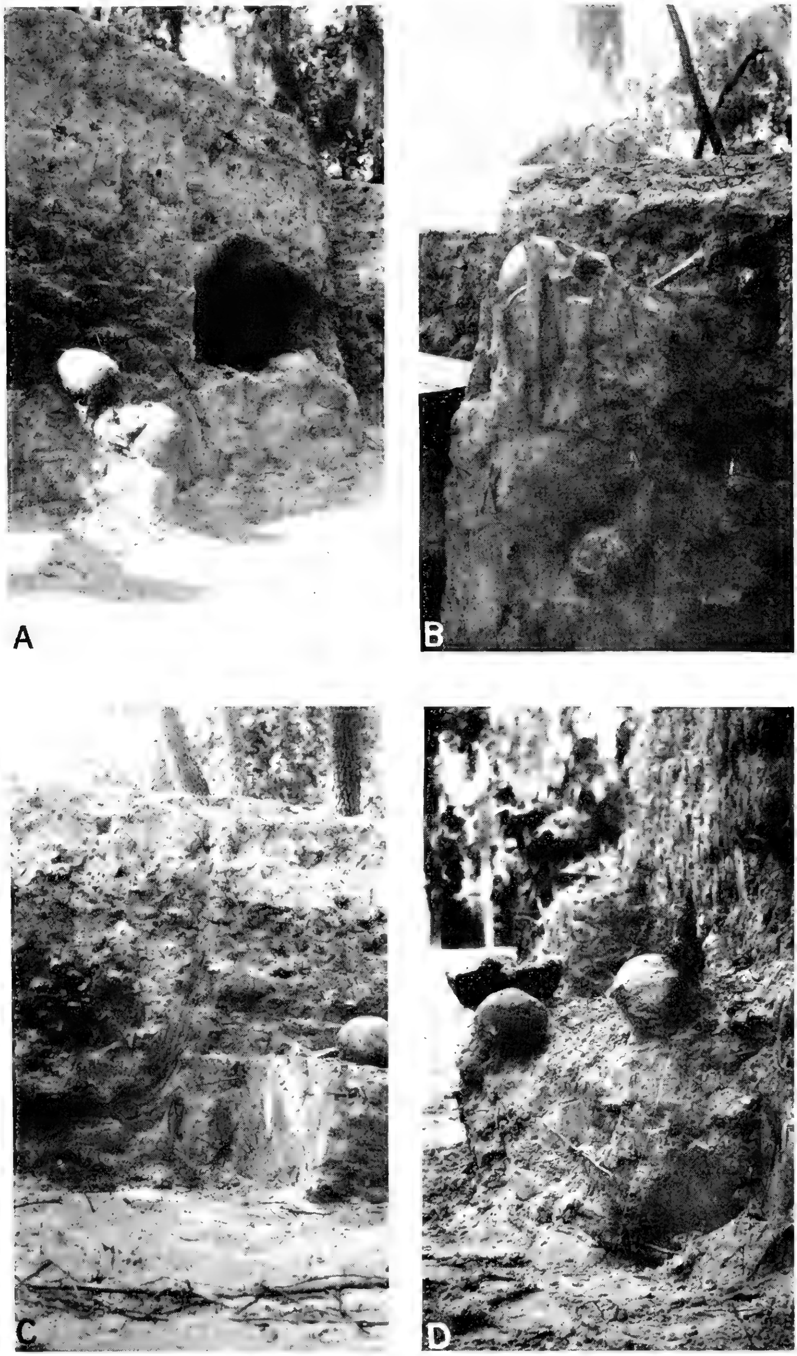
Views in trench of Weeden Mound, St. Petersburg, Florida.

A. Large undecorated food bowl on top of lower layer.
B. Mr. Reichard repairing bowl A.
C. Tree growing in upper layer above burial.
D. Food bowl A on top of lower layer.



Sections of Weeden Mound excavation.

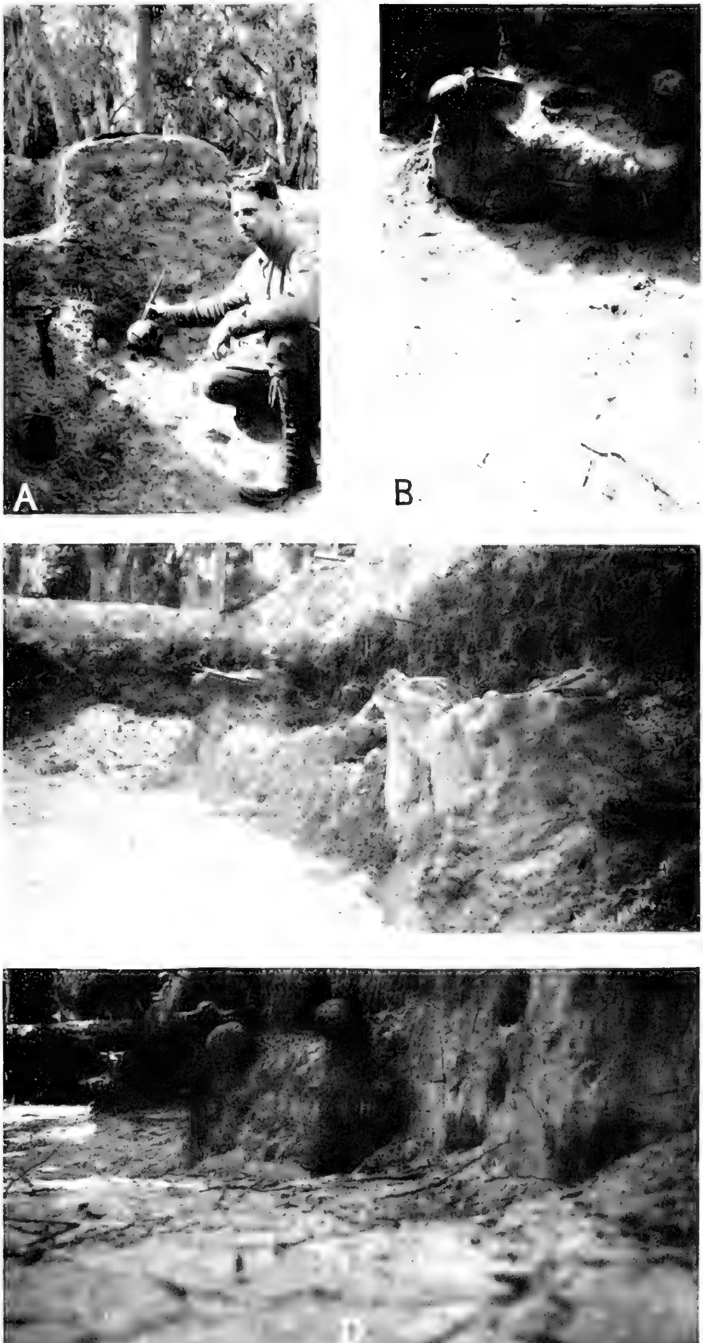
A. Human skulls on lower layer.
B. Skulls on lower layer, with long bones.
C. Shallow burial on upper layer just below surface.
D. Section of mound showing burials on upper and lower layers.



Sections of Weeden Mound.

A. Two skulls in lower layer. Black food bowl removed.
B. Bundle burial in upper layer near surface.
C. Skull on top lower layer.
D. Skulls on top lower layer.

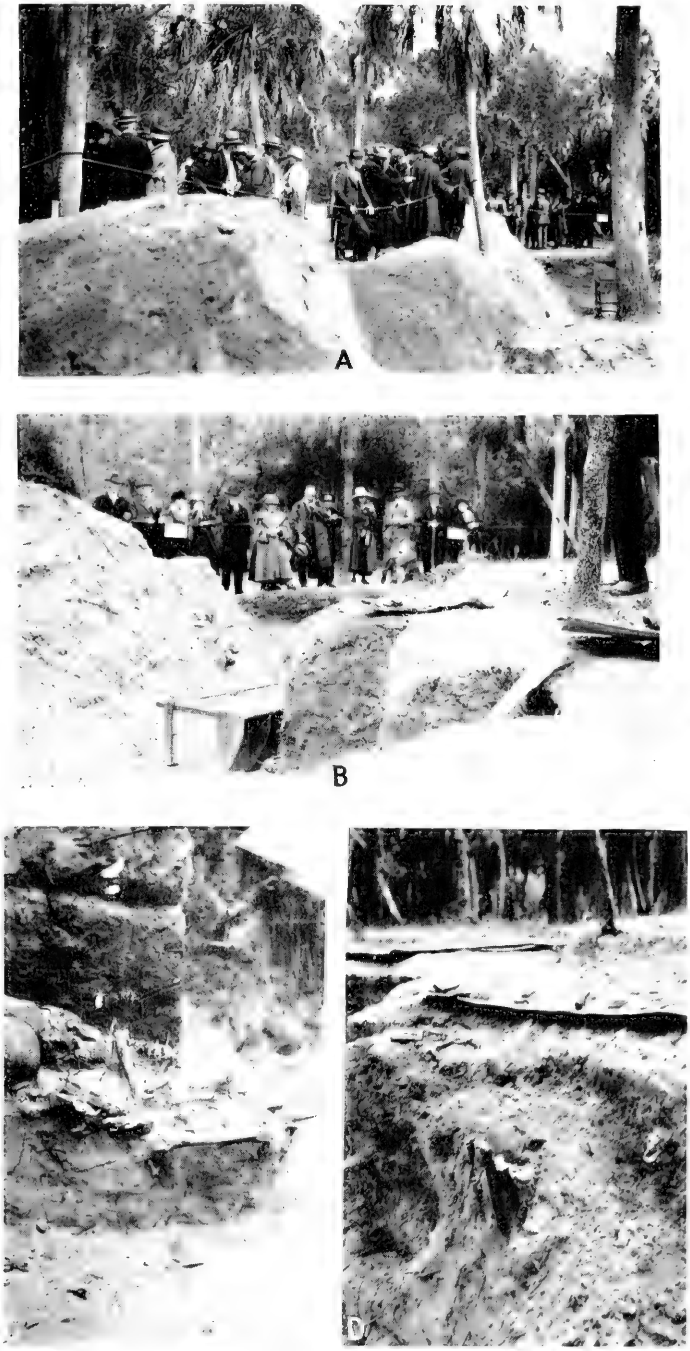
Photographs by D. L. Reichard.



Sections of excavations at Weeden Mound, St. Petersburg, Florida.

A. Mr. Reichard indicating position of skull.
B. Skulls in lower level.
C. Burials in black sand above lower layer.
D. Skulls *in situ*. The dark sand represents the lower part of the upper layer.

Photographs by D. L. Reichard.



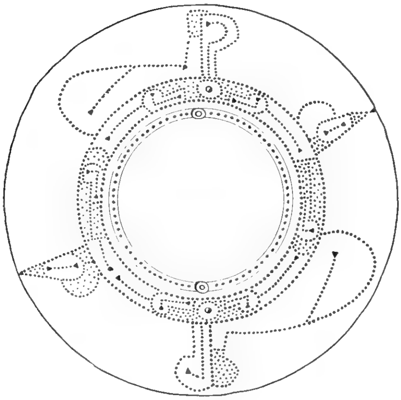
Views of excavations, Weeden Mound, St. Petersburg, Florida.

A. Visitors standing on dump.
B. Visitors at end of trench.
C. Two layers in section of mound.
D. Secondary burial in upper layer near surfaces showing ends of large bones vertically placed.

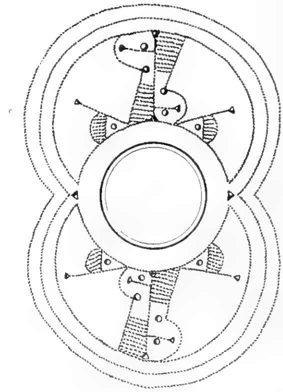
Photographs by D. L. Reichard.

Pottery from Weeden Mound (Upper layer).

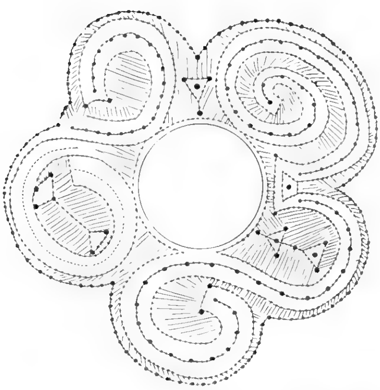
A, A. Decoration of same bowl from two sides. Size 7¾" by 6½".
B. Spherical bowl from one side. Size 8" by 6¾".
C. Bowl with snake figures. Size 10¼" by 7".
D, D. Two views of same bowl, different diameters. Size 6" by 6½" by 5".
(Taken from a cache near surface.)



A



B



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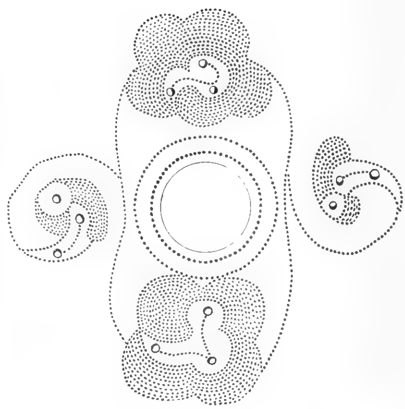
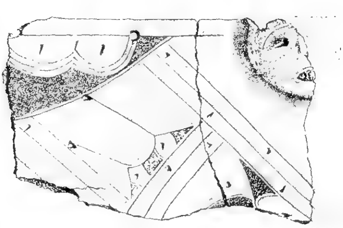
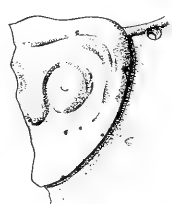


D



E



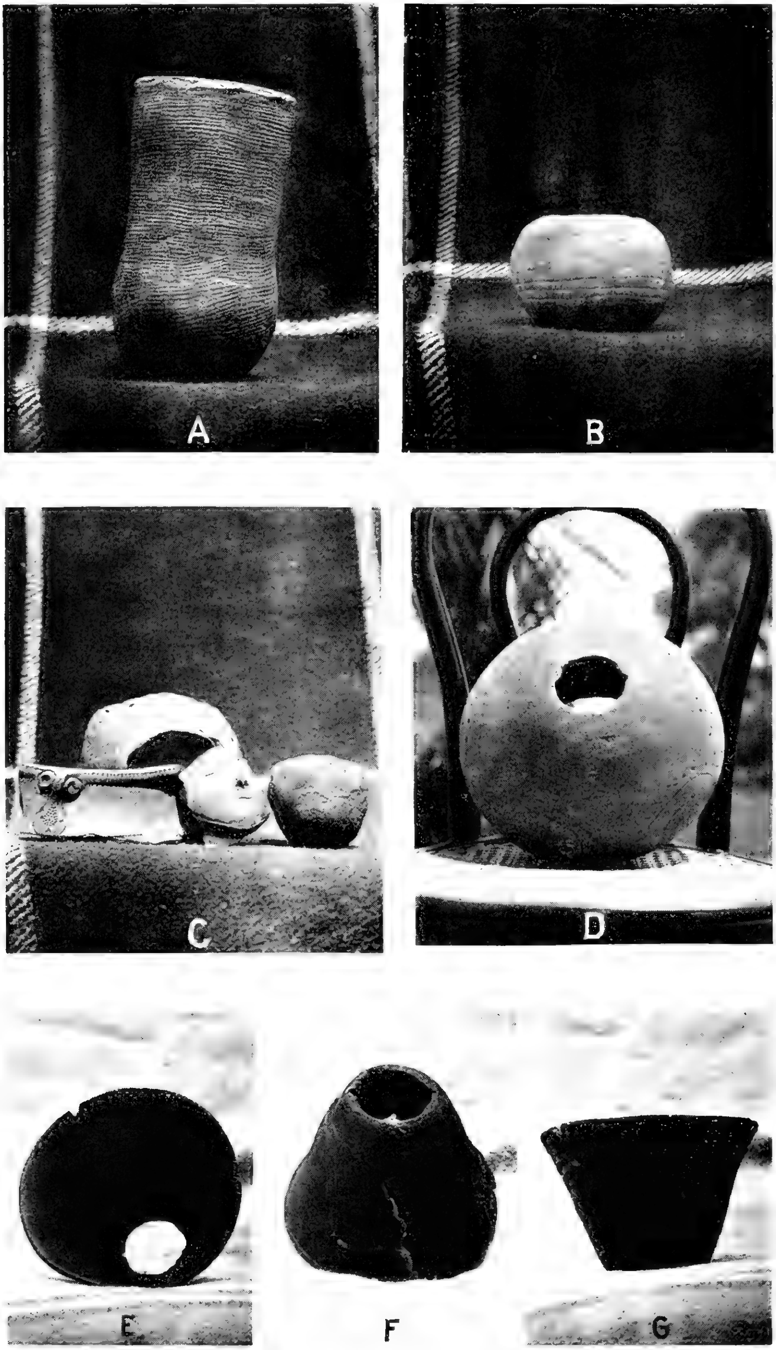
F

Mullett.

Designs on bowls A-D from above.

A, plate 9, fig. A; B, plate 9, fig. B; C, plate 9, fig. C; D, plate 9, fig. D; E, human face in relief on edge of bowl; F, another head in relief on edge of bowl.

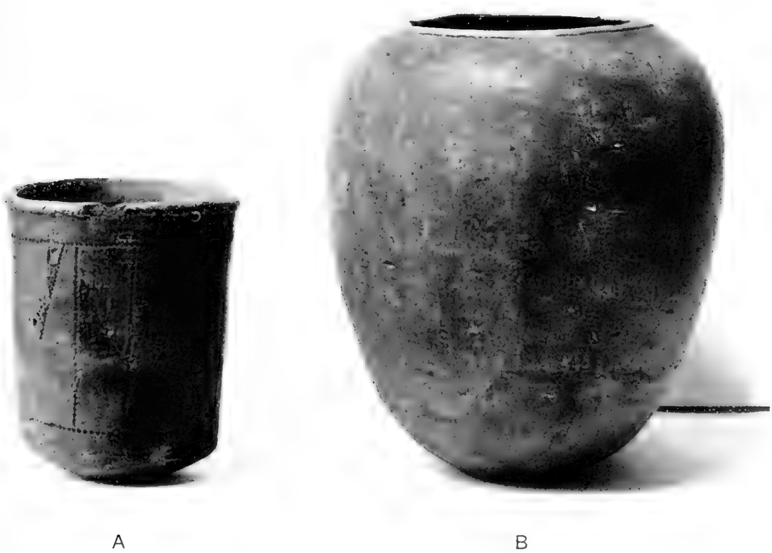
Two views of a jar found in fragments and restored. Size 6″ by 15″. Shows designs made with punctures, and circular depressions made with cane.



Pottery from upper layer, Weeden Mound, St. Petersburg, Florida.

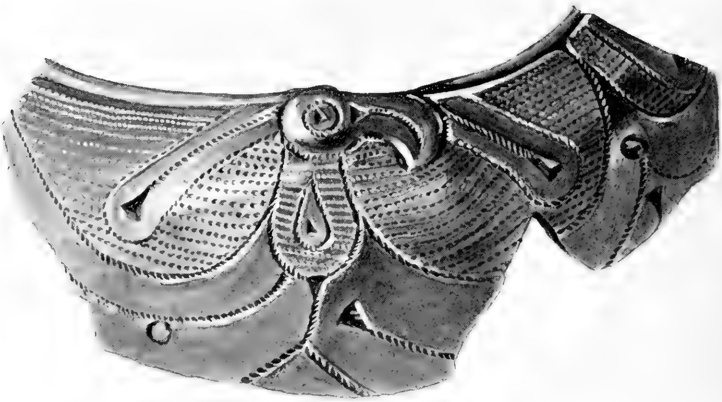
A. Deep vase with coiled incised decoration.
B. Globular bowl with incised decoration.
C. Human face and pottery shards.
D. Globular decorated bowl showing perforation ("killing").
E, F, G. Three views of conical bowl.

1. Gourd showing figures made by puncturing. Cuba. Size, 9″ diameter; 8½″ height



A B

2. Pottery vessels, from near surface. *A*, size 5″ by 6″; *B*, size 8¼″ by 9″.



A

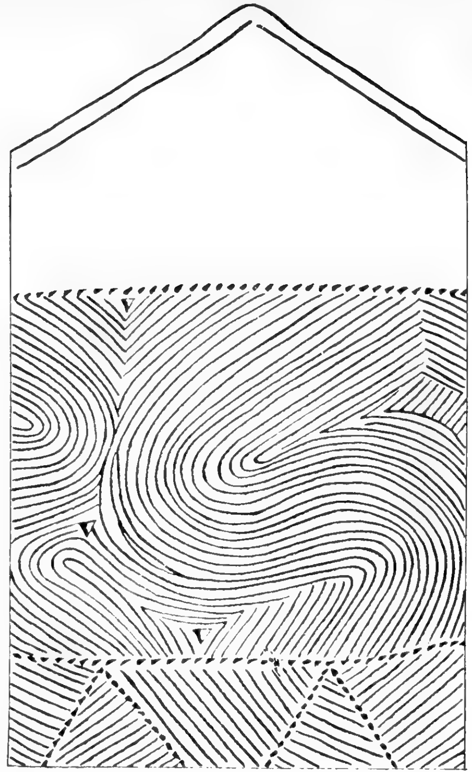
Mullett.

B

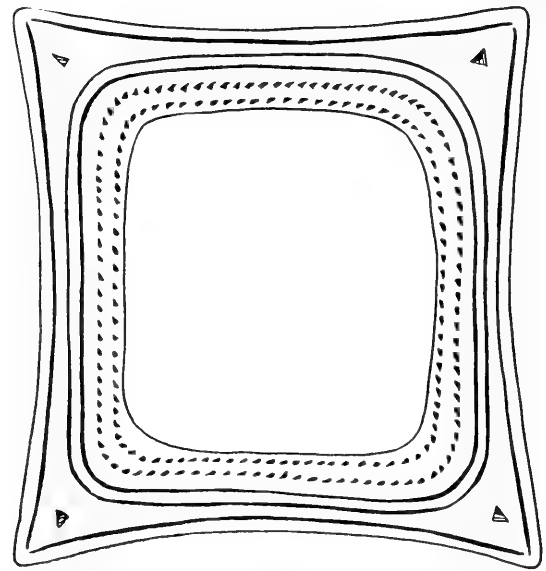
Ceramic objects from Weeden Mound.

A. Fragment of a food bowl or ceremonial vessel decorated with bird design. Size, 6¾″ by 6¼″.

B. Deep rough bowl with stamped decoration. Height, 11½″.



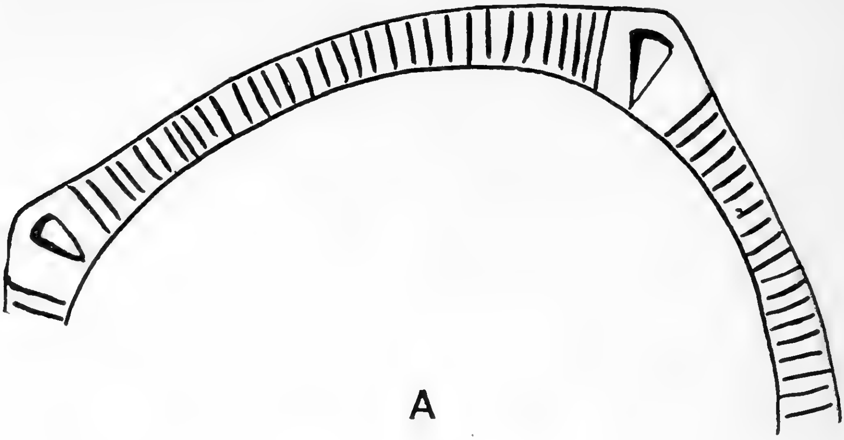
A



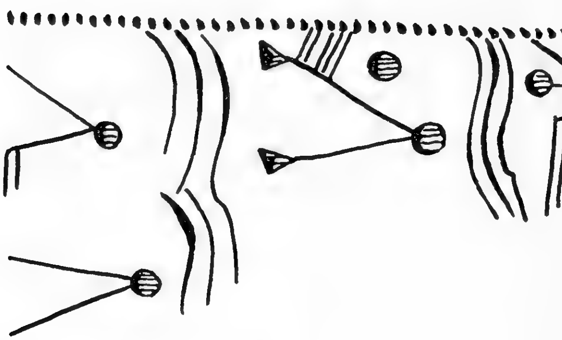
B

Mullett.

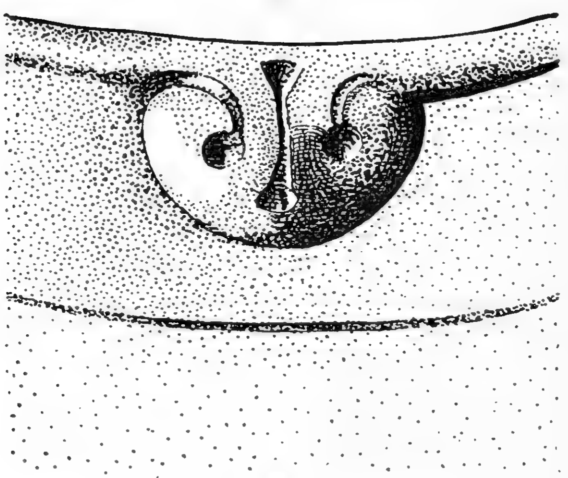
Lateral and top decorations of a deep cubical jar from Weeden Mound, St. Petersburg, Florida. (From a fragment.)



A



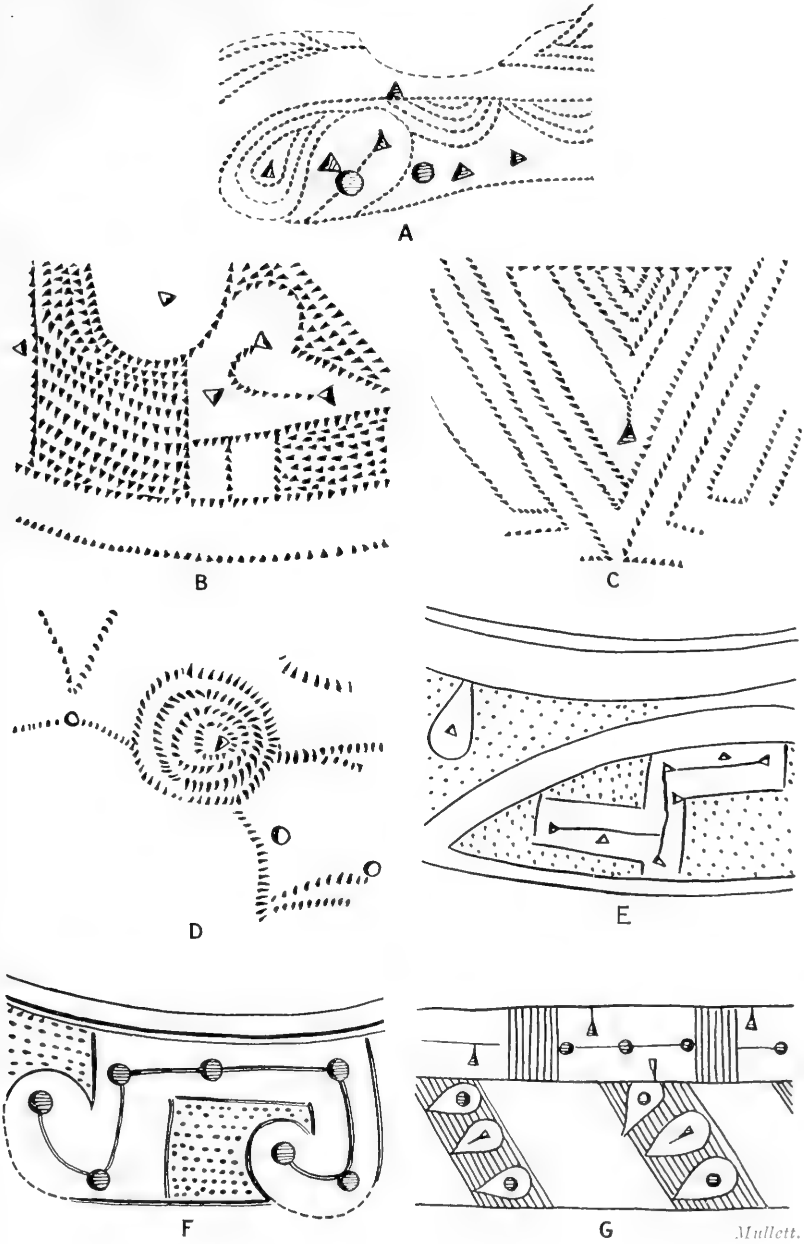
B



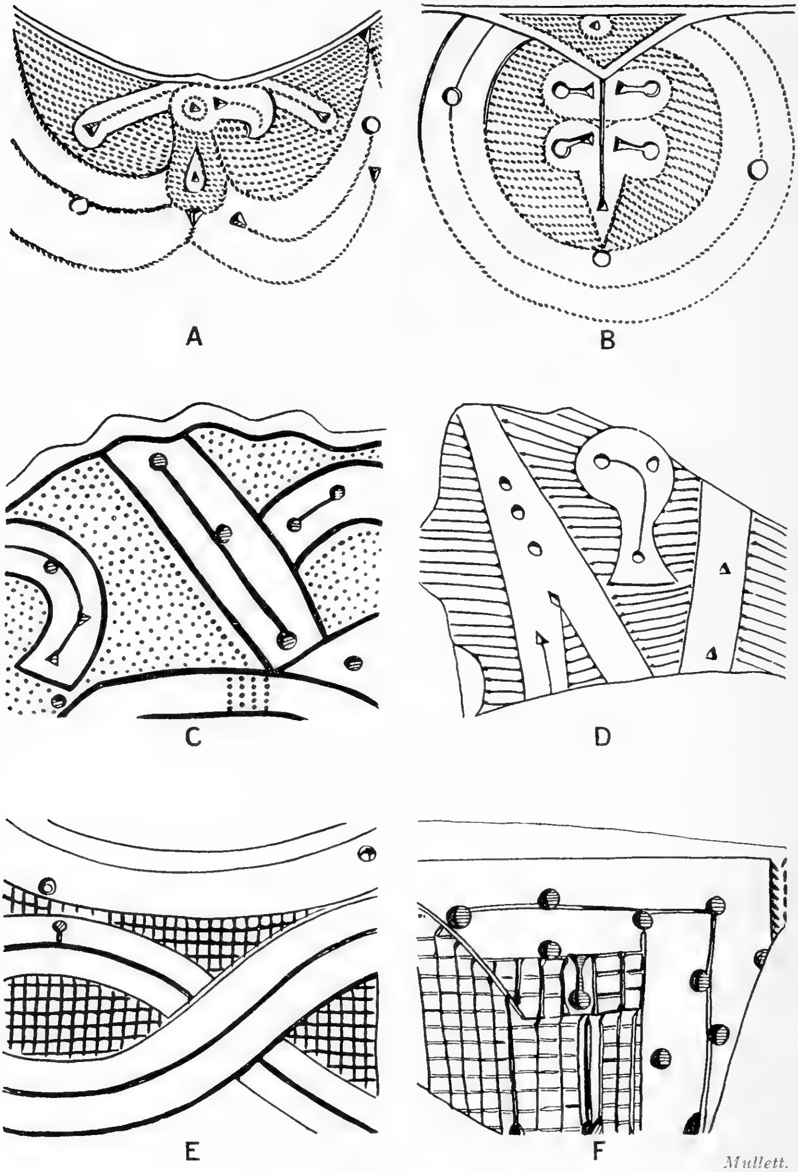
C

Mullett.

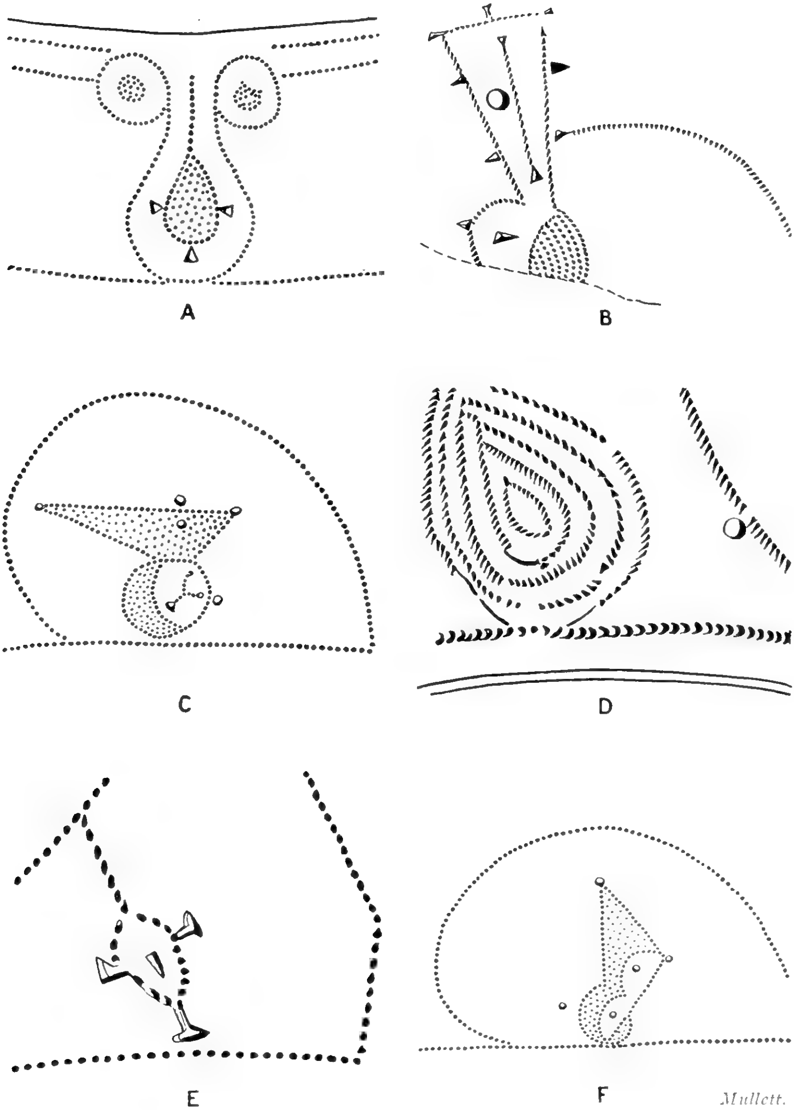
Various designs made with punctate or other incised figures on pottery fragments from Weeden Mound.



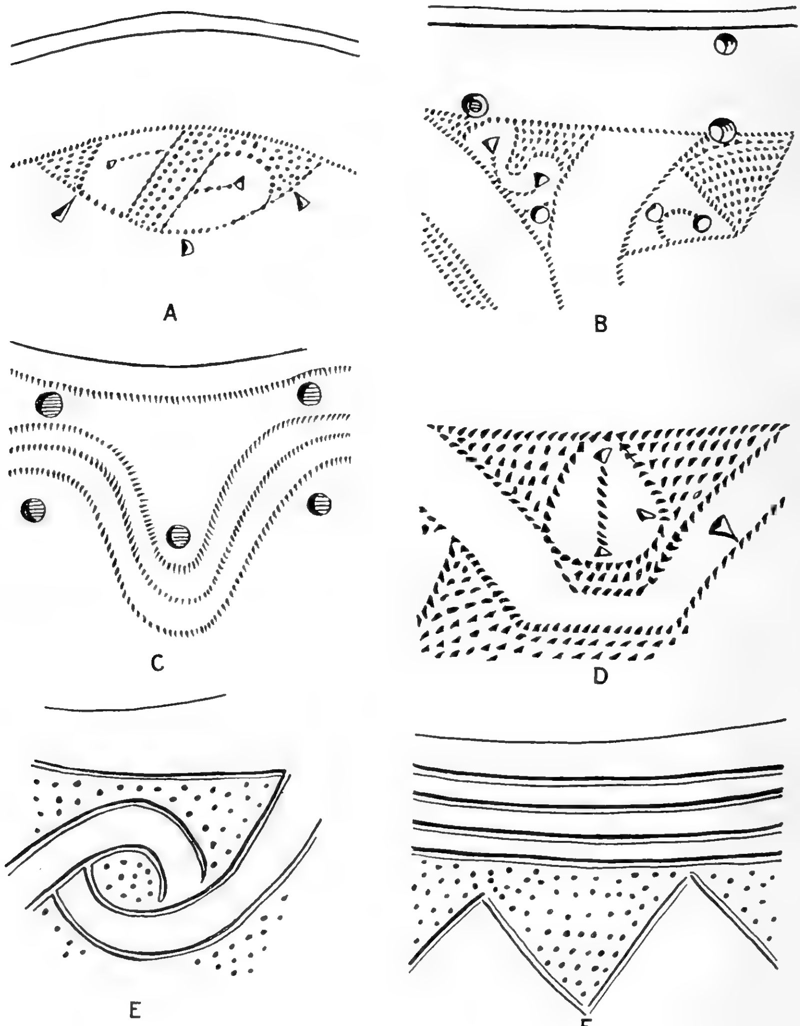
Various designs made with punctate or other incised figures on pottery fragments from Weeden Mound.



Various designs made with punctations on pottery fragments.

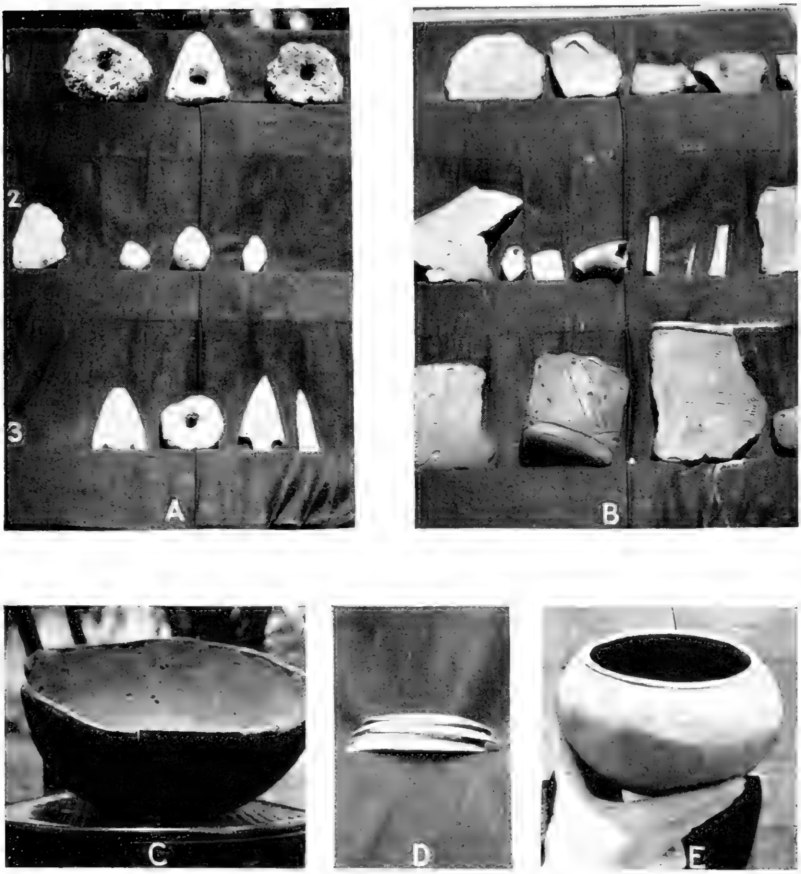


Various designs made with punctations on Weeden Mound pottery. *A* and *D*, rim below; *B, C, E, F,* no rim shown.



Mullett.

Various designs made with punctations on pottery fragments.



Various artifacts from Weeden Mound.

A. Stone objects. B. Fragments of pottery.
C. Coarse food bowl. D. Cluster of sun shells.
E. Globular bowl without decorations.
Photographs by D. L. Reichard.