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SMITHSONIAN

MISCELLANEOUS COLLECTIONS

VOL. 87

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

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

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THE BOTANICAL COLLECTIONS OF WILLIAM LOBB IN COLOMBIA

BY
ELLSWORTH P. KILLIP
Associate Curator, Division of Plants,
U. S. National Museum

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The name of William Lobb is closely associated with botanical exploration in western South America, and there are numerous references in literature to his collections from the Andes. While studying the distribution of certain species of Andean plants, I have found it necessary to examine rather carefully these references, especially those in which the specimens are mentioned merely as "Peru, Lobb," or "Columbia, Lobb." Although these studies have been by no means exhaustive, and positive conclusions are perhaps not yet justified, it seems worth while to present the results of my preliminary investigations.

My interest in the subject was first aroused by observing the unusual distribution of various species of Passifloraceae given in Masters' monograph [1] of the family. There were numerous instances of a species being reported from Colombia solely on the basis of a Lobb collection, all other specimens cited being from Peru or southern Ecuador. More remarkable was the fact that my examination of collections not included in Masters' monograph or made subsequent to its publication showed that in the same instances this additional material came from Peru or southern Ecuador, never from Colombia. Turning to other plant families I found that a similar situation existed.

The question at once presented itself: Did Lobb chance to visit a part of Colombia with a characteristic Peruvian or southern Ecuadorean flora, never before or since explored by botanists, or has there been an error in the labeling of some of his specimens, certain Peruvian and Ecuadorean ones being labeled "Colombia"? The importance of answering this question is obvious: If the "Colombia" specimens actually came from Peru, many species must be eliminated in listing the known plants of Colombia, and conversely, in preparing a flora of Peru, many species hitherto supposed to have been endemic to Colombia must be accounted for. It should be noted that although

[1] Mart. Fl. Bras. **13** [1]: 530-654. 1872.

there is a great similarity between the flora of the southeastern Colombian lowlands and that of eastern Ecuador and northeastern Peru, all strictly Amazonian in character, in the mountains a much smaller number of species are common to both Colombia and Peru, and these invariably are to be found throughout the Ecuadorean mountains. The Lobb "Colombia" collections are mainly mountain types.

In investigating this subject I have been greatly assisted by Mr. S. C. Skan, the assistant librarian of the Royal Botanic Gardens, Kew, who has forwarded copies of papers relating to Lobb which are preserved there, and by Dr. H. A. Gleason, Dr. I. M. Johnston, and Mr. A. C. Smith, partly for examining questionable Lobb specimens for me and partly for supplying information about Lobb collections represented in groups they are studying.

LOBB'S ITINERARY

Definite information concerning Lobb's itinerary in South America is difficult to obtain. William Lobb was for many years (1840-1857) a collector for the well-known horticultural firm of James Veitch and Sons, of London. In 1906 the firm published the "Hortus Veitchii,"[2] a work containing biographical sketches of the numerous collectors sent out by the firm, as well as lists of the more important plants collected and introduced into European horticulture through their efforts. Of William Lobb it is stated:[3]

> . . . . he gladly accepted a proposal . . . . to go on a mission to various parts of South America for the purpose of collecting plants, and he sailed from Plymouth in 1840 for Rio Janeiro. On his arrival in Brazil he first proceeded to the Orgáos Mountains, ... he then left for Chile, crossing the great pampas of the Argentine Republic and the Chilean Andes. Continuing southwards, Lobb penetrated the great Araucaria forests . . . .
>
> He returned to England in 1844, renewed his engagement, and sailed again for Brazil in April of the following year.
>
> After sending home from Rio Janeiro a consignment of plants collected in Southern Brazil, he proceeded to Valparaiso for the purpose of exploring Southern Chile . . . .
>
> Following up these brilliant achievements, he continued explorations in Valdivia, Chiloe, and Northern Patagonia . . . . Lobb returned to England in 1848.

---

[2] Pp. 37-40. This account of William Lobb is taken from Veitch's Manual of Coniferae, compiled by Adolphus Kent. No additional information bearing on Lobb's route is given in the earlier work.

[3] Pp. 37 sq.

The remainder of this account deals with Lobb's travels in the western United States between 1849 and the time of his death in San Francisco in 1857.

It will be seen that no mention is made here of his travels in the Andes north of Chile. From statements in the accounts of the plants received by the Veitch firm from Lobb from Peru and northward in the Andes, as well as from references to Lobb's collections in Curtis's Botanical Magazine and similar publications, it appears that this part of Lobb's explorations was made between 1842 and 1843.

No letters written by Lobb while in South America are extant apparently. The firm of James Veitch and Sons having been discontinued, Mr. Skan kindly sought information from a former employee of the firm, who replied,

> Apparently Lobb's letters were available when Adolphus Kent compiled Veitch's Manual of Coniferae, but they were not with the firm in my time. The only letters relating to Lobb which I saw were copies of the letters sent by the firm *to* Lobb. These were in a private letter book and were no doubt destroyed when the firm was wound up.
>
> In Lobb's time letters were few and far between and I have always understood that the Lobbs said and wrote little about either their finds or their travels.

Two letters in the Kew Library [4] bear upon Lobb's travels:

> Ed. Michel to W. Jameson.
>
> Guayaquil, Nov. 15, 1843.
>
> Mr. Lobb arrived here from Panama on the 28th ult. and embarked same day on board of the steamer Peru for Callao.—7 boxes of plants to which Mr. Veitch refers were left by Mr. Lobb at the English Consul House at Puna [a settlement on an island in Guayaquil Bay] and were never forwarded to Panama. Mr. Lobb wrote from Guayaquil to Mr. Veitch explaining the occurrence and his letter will no doubt be a satisfactory reply to all Mr. V. inquiries. The boxes Mr. Lobb left on his first arrival in this country and on examination when he was last here he found, I believe, that the plants were in an unfit state to be sent forward and they were thrown away as useless.
>
> Seeman's letter of July 28, 1847, from Paita.
>
> Mr. Lobb speaks to me of Loxa and Cuenca in most extravagant terms—of all the parts of the interior he has visited he considers them the most beautiful and calls them the "Garden of South America."

Lobb probably made herbarium specimens of most of the plants represented in the material sent to Europe for horticultural purposes, though apparently some of them were lost. He does not appear to have made more than a single specimen of each, and these are deposited at Kew, the inscriptions on the sheets invariably being "Columbia, Lobb," "Peru, Lobb," and the like.

---

[4] Hooker Corresp. vol. 19: no. 219, at Kew.

The most helpful clues to Lobb's Andean itineraries are to be found in the list of plants introduced into horticulture through Lobb, given in the Hortus Veitchii, and in a manuscript "List of Dried Specimens from William Lobb from South America, July 1843," which is preserved in the Kew Library.

In the Veitch list of plants obtained by their collectors, there are numerous references to the collections of William Lobb, mainly to those obtained in Brazil, Argentina, Chile, and Peru, and there is little reason to question the correctness of the data as to the place of origin of his material from those countries. Three Ecuadorean plants of Lobb's are mentioned, *Calceolaria crenata*, from Quito, and *Macleania punctata*, and *Tacsonia mollissima*, all of which are known to occur in that country. Of the four "Colombian" plants of Lobb's given in this account, *Fuchsia macrantha* most probably came from Peru, not Colombia (see page 10), and *Tropaeolum lobbianum* from southern Ecuador; *Tropaeolum smithii* may have come from Colombia; *Heterotrichum macrodon* is otherwise known only from Venezuela, and the identity of the Lobb plant and its place of origin are uncertain at present.

In the "List of Dried Specimens" there are recorded 117 plants; to each a number is given and with each is associated a brief note as to the character of the plant, the color of the flowers, and locality data. For 31 of these, various localities in southwestern Colombia are given. A transcript of a part of the data for the Colombian entries follows:

20. Tropaeolum	Pro. Pasto New Granad.	9000 ft.
30. Befaria grandiflora	Pro. Pasto New Granada	9000 ft.
52. Calceolaria	Near Guachucal	5000 ft.
61. Besleria	Pasto New Granada	7000 ft.
81. Thibaudia	Pasto New Granada	6000 ft.
82. "	near Barbacosa	....
83. "	do do	
85. Besleria	near Pilispi P. Pasto	4000 ft.
86. Plant	Pro. Pasto	6000 ft.
87. Fuchsia	do do	7000 ft.
88. Plant Herb	Near Pilispi do	5000 ft.
89. Shrub	do do do	5000 ft.
90. Shrub	do do do	5000 ft.
91. Plant procumbent	n. Barbacosa	....
92. Plant	n. Barbacosa, Pr. Popayan	....
93. Gloxinia	do do do	....
94. do	near Barbacosa	
106. Atropa	Near Guachucal Pr. Pasto	7000 ft.
107. Gesneria	near Pilispi	5000 ft.
172. Plant Prostrate	near Barbacosa P. Popayan	......

175. Plant	near Barbacosa	....
176. Siphocampylus	Prov. Pasto	....
179. Utricularia	Near Barbacosa	....
180. Herb	do do	....
181. do	do do	....
182. Aquatic	Laguna (illegible) Pr. Popayan	....
183. Aquatic	do " do	....
Orchideae		
0.1 Epidendron	Molletura, P. Popayan Equator	6000 ft.
2. do	Pilispi P. Pasto	6000 ft.
11. Oncidium	P. Pasto	8000 ft.
12. "	near Pilispi	5000 ft.

Presumably these specimens are in the Kew herbarium, but unfortunately I have had no opportunity of examining them and ascertaining whether they represent characteristic Colombian species or Peruvian ones not otherwise known to occur in Colombia. However, from Mr. Smith's examination of the Thibaudieae, it appears that all of these may well have come from southern Colombia; certainly there is no indication of a Peruvian origin.

The localities on this list are mainly in the extreme southwestern part of Colombia, and are all in the present Department of Nariño, formed from portions of the earlier provinces of Popayán and Pasto. Barbacosa is doubtless the city of Barbacoas, on the Patía River near the coast, at an elevation of about 100 feet. Pasto, the capital of Nariño, is situated in the mountains on the main route of travel from Quito to Popayán. Guachucal is a town about 50 miles southwest of Pasto, and is one of the localities at which Humboldt collected. Pilispi I have not been able to find on any map or in any gazetteer of Colombia, Ecuador, or Peru. The insertion of the words "P. Popayán" in the first orchid entry is clearly a clerical error, as elsewhere on the list "Molletura, Prov. Cuenca," [Ecuador] appears.

From this it seems evident that Lobb did visit the southwestern part of Colombia, perhaps by going overland from Quito to Pasto, descending to Barbacoas, and boarding a ship at the port of Tumaco, or perhaps by stopping off at Tumaco and making a hurried trip to Pasto and return. I am confident that the plants he collected will all prove to be characteristic Colombian or northern Ecuadorean species, most of them probably represented in the subsequent collections of André and Lehmann, and that one need not expect to find in this region the characteristic Peruvian, or even southern Ecuadorean, species, as botanical literature would indicate.

The political division of northwestern South America during the past century may be briefly noted here. From 1810 to 1831 the present Venezuela, Colombia, and Ecuador were united in one political unit, the Republic of Colombia; in 1831 these countries became separate republics under the names Venezuela, Nueva Granada, and Ecuador. The name Nueva Granada was changed in 1861 to that of the United States of Colombia, and in 1886 to the Republic of Colombia. The boundaries between the three countries, either as entities or as parts of the early Republic of Colombia, have been substantially the same as they are today. The name Colombia has never been properly applied to Peru. In Lobb's time the three countries, Venezuela, Nueva Granada, and Ecuador, were distinct, and it is doubtful if Lobb ever used the term " Colombia," even for his New Granada collections. However, there is every indication that botanical students, of the present day as well as a hundred years ago, working far from the field, have had a very hazy idea of the political divisions and the geography of South America, and have used the names of the countries with much laxity. Doubtless those who first examined the Lobb mounted specimens wrote on the sheets indiscriminately " Peru " or " Columbia."

CITATIONS IN LITERATURE

As a collector of plants for horticultural purposes, Lobb gave special attention to such groups as *Passiflora, Fuchsia, Tropaeolum, Bomarea,* and *Thibaudieae,* and it is in these groups that we find the greatest number of Lobb collections cited. The following list contains all citations of Lobb's specimens, including those in the lists mentioned above, that bear upon the questionable Colombian collections, which so far have come to my attention.

AMARYLLIDACEAE

Baker, Handbook Amaryllideae 1888

EUCHARIS GRANDIFLORA Planch.

Page 110. "Andes of New Granada, *Lobb! Jameson! Lehmann! André!* Introduced into cultivation in 1854 through M. Linden."

Based originally upon a plant from the Chocó, in northwestern Colombia, the species ranges south through Ecuador to northern Peru. Jameson collected only in Ecuador, Lehmann and André in both Ecuador and Colombia. Most of the material in the National Herbarium is from Ecuador. The Lobb specimens therefore may have come from either Colombia or Ecuador.

BOMAREA PHYLLOSTACHYA Mast.

Page 144. "Andes of Columbia, *Lobb!*"

The species of *Bomarea* to which this is most closely related range from Colombia to Peru. Kränzlin has described [5] a plant *B. stricta,* based upon a Lobb specimen from *Peru,* which differs from *B. phyllostachya* only in slightly smaller leaves and flowers. I strongly suspect that the type of *B. phyllostachya* came from Peru, and may even be a part of the same collection upon which *B. stricta* is based.

BOMAREA GLOMERATA Herb.

Page 148. "Andes of Columbia and Peru, *Mathews* 1662! *Lobb* 256!"

As Mathews collected only in Peru, the "Columbia" reference must have been to the Lobb plant. I can not separate *B. glomerata* from the common Peruvian plant *B. setacea* R. & P., which is not known to occur in Colombia. In all probability Lobb's 256 is from Peru.

BOMAREA FORMOSISSIMA (R. & P.) Herb.

Page 153. "Andes of Peru, *Pavon!* . . . . Columbian specimens from Lobb and Bolivian from Pearce agree substantially with Pavon's."

This is the only Colombian record for one of the most showy of Peruvian Bomareas. The Hartweg plant, from the vicinity of Bogotá cited [6] by Bentham as *B. formosissima* has been shown by Baker to be a distinct species, to which he gave the name *B. herbertiana.*

BOMAREA PARDINA Herb.

Page 158. "Andes of New Granada and Ecuador, gathered recently by Lobb, Spruce, Pearce, and André."

Spruce and Pearce did not collect in Colombia, but both made large Ecuadorean collections. André's plant came from Ecuador. Doubtless the Lobb plant was obtained in southern Ecuador.

TROPAEOLACEAE

TROPAEOLUM LOBBIANUM Veitch

Hooker states,[7] "It was detected by a Veitch collector, Mr. Lobb, in Columbia, and sent home in the early part of 1843."

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[5] Ann. Nat. Hofm. Wien **27**: 156. 1913.

[6] Pl. Hartw. 259. 1846.

[7] Bot. Mag. Curtis **70**: *pl. 4097.* 1844.

As Buchenau has shown,[8] this is the same as *T. peltophorum* Benth., described from Ecuador a year earlier. All material of this species which I have seen comes from Ecuador. This and the following species are both listed in the Hortus Veitchii (page 438).

TROPAEOLUM SMITHII DC.

The entry in the Hortus Veitchii gives Colombia for this collection of Lobb's. The species ranges from Venezuela to Ecuador, so the Lobb plant may have come from either Colombia or Ecuador.

There are nine entries of *Tropaeolum* in the " List of Dried Specimens," of which eight are associated with places in Ecuador and one is from Colombia.

PASSIFLORACEAE

Masters in Mart. Fl. Bras. 13[1]: 530-627. 1872.

PASSIFLORA TRIFOLIATA Cav. (*Tacsonia trifoliata* Juss.)

Page 538. " Habitat in Peruvia: Ruiz et Pavon! Gay! Mathews n. 674! 675! Cruikshanks! MacLean!; et in Columbia: Lobb n. 20! "

This is a common species of the high mountains of central Peru, and Lobb's collection was almost certainly made there.

PASSIFLORA AMPULLACEA (Mast.) Harms. (*Tacsonia ampullacea* Mast.)

Page 539. " Habitat in Ecuador prope Cuenca: Jameson!; in Nova Granada: Lobb! "

The Lobb specimen is a perfect match for the Jameson plant as well as for Lehmann's 4602, the type of *Passiflora hieronymi* Harms, from the western Andes of Cuenca. The latter species must be reduced to synonymy. The Lobb plant doubtless came from the vicinity of Cuenca where he made large collections.

PASSIFLORA URCEOLATA (Mast.) Killip (*Tacsonia urceolata Mast.*)

Page 539. " Habitat in Colombia: Lobb n. 121! "

This species is known only from the single type specimen, so that conclusions as to the precise locality are difficult to draw. Inasmuch as its nearest relatives, *P. ampullacea* and *P. matthewsii* are from southern Ecuador and northern Peru, respectively, it is probable that it, too, came from that general region.

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[8] Pflanzenreich IV[131]: 21. 1902.

Passiflora parvifolia (DC.) Harms (*Tacsonia parvifolia* DC.)

Page 540. "Habitat in Columbia: Lobb!; in Peruvia: Ruiz et Pavon!; in Ecuador: Pearce."

This plant has been found in Peru by recent collectors, but never in Colombia or Ecuador. There are two sheets in Kew herbarium, one labeled "Lobb, Peruvia," the other "Lobb, Columbia." There is every indication that these specimens were collected at the same time and even from the same plant, the degree of development of the flowers and the discoloration of the specimens being very similar. The Pearce plant from Ecuador (no. 35) was wrongly identified as *P. parvifolia* by Masters; it proves to be *P. cumbalensis* (Karst.) Harms.

Passiflora mollissima (H. B. K.) Bailey (*Tacsonia mollissima* H. B. K.)

Page 541. Under *Tacsonia mollissima* var. *glabrescens* Masters cites two collections, "In Ecuador ad Cuenca: Seemann 823!; in Columbia: Lobb!"

Passiflora mollissima is widely distributed in the Andes from Venezuela to Peru, the form with glabrescent upper leaf surfaces being found throughout the range. No conclusions regarding the origin of the Lobb specimen are therefore possible.

Passiflora lobbii Mast.

Page 533. "Habitat in Columbia: Lobb!"

This plant has been collected in recent years in central Peru by Weberbauer, Killip and Smith, and Macbride, but never in Colombia. A Weberbauer specimen has been made the type of *P. obtusiloba* var. *glandulifera* Harms.[9] Although *P. lobbii* and *P. obtusiloba* have a similar general appearance, the two are separated on several characters other than the presence or absence of petiolar glands. I am convinced that both species are restricted to central Peru.

Passiflora sanguinolenta Mast.

Page 559. "Habitat in Columbia: Wallis!; in Peruvia (?): Lobb 151!"

All other collections of the species are from southern Ecuador, where these two perhaps also were collected. On the Lobb sheet is inscribed "Peru," and this is the only instance I have yet discovered of a Lobb specimen apparently being mislabeled "Peru."

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[9] Repert. Sp. Nov. Fedde **19**: 25. 1923.

LOASACEAE

Cajophora cymbifera Urb. & Gilg.

Urb. & Gilg, Monographia Loasacearum 281, 1900. "Habitat in Columbia: Lobb," this collection being the type and only one of the species known.

Of the 57 species of *Cajophora* treated by Urban and Gilg, this is the only one recorded from Colombia, and only one other, *C. aequatoriana,* is known to occur north of the Peru-Ecuador boundary. The Lobb plant is probably from central Peru. Under *C. aequatoriana* the authors observe that a depauperate specimen in the Kew herbarium, said to have been collected by Lobb " in Columbia," perhaps is referable to that species. *Cajophora aequatoriana* ranges from Quito, Ecuador, to northern Peru, and the Lobb plant in question may well have come from southern Ecuador.

MELASTOMACEAE

Heterotrichum macrodon Planch.

In Hortus Veitchii (page 264) and Curtis's Botanical Magazine this is said to have been raised in England from seed sent by William Lobb from New Granada. The species is known otherwise only from northern Venezuela. Pending examination of the Lobb specimen, it is impossible to suggest an explanation for this apparently unusual distribution.

ONAGRACEAE

Fuchsia macrantha Hook.

In proposing [10] this species Hooker says, " It . . . . is an undescribed species, first, however, found by Mr. Mathews climbing on trees in lofty mountains at Andimarca, Peru, ... and next by Mr. Veitch's collector, Mr. William Lobb, detected in woods near Chasula, Columbia, at an elevation of 5,000 feet above the sea." This is also one of the Lobb Colombian plants listed in the Hortus Veitchii (page 264).

All the material of this species in the National Herbarium is from Peru, and I have been unable to find any other record for Colombia. " Chasula " does not appear in Colombian gazetteers, but there is a town Chasuta, not far from Andamarca, in the mountains of north-central Peru, and another town Chagula in central Peru, and it is not unreasonable to suppose that this plant may have come from one of these places.

[10] Bot. Mag. Curtis **72**: *pl. 4233*. 1846.

VACCINIACEAE—THIBAUDIEAE

(Information supplied by A. C. Smith, New York Botanical Garden, based upon a monographic treatment of the tribe, in press, and an examination of specimens in the Kew herbarium.)

CERATOSTEMA BUXIFOLIUM Field. & Gardn.

"Lobb 2, Columbia" on specimen.

This is probably the type of *Thibaudia microphylla* Lindl., which is a synonym of *Ceratostema buxifolium*. This specimen certainly is from Peru.

CERATOSTEMA GRANDIFLORUM R. & P.

"Lobb 3, Columbia" on specimen.

All other specimens belonging to this species are Peruvian.

CERATOSTEMA *sp.*

"Lobb 252, Columbia" on specimen.

This represents an undescribed species which Mr. Smith has in manuscript. All other Ceratostemas of this affinity are from Peru, and doubtless this is also.

ENGLERODOXA ALATA Hoer.

Lobb 80, 161.

One of these sheets is labeled "Columbia." All other material of this species is from Ecuador. In the "List of Dried Specimens" the entry for no. 80 reads, "Thibaudia, shrub 3 to 4 ft., high mountains, Pro. Cuenca Ecuador."

THIBAUDIA MELLIFLORA R. & P.

There is in the Kew herbarium a sheet labeled "Columbia, Lobb," which has been identified as *Thibaudia melliflora* R. & P., a species otherwise known only from central Peru, the type specimen probably from the Department of Huánuco.

MACLEANIA MACRANTHA Benth.

"Lobb 82, woods, Barbasopa, Columbia" on specimen.

This number is included in the "List of Dried Specimens." As already pointed out, the locality probably is Barbacoas, Colombia. This species was originally described from the Pichincha region of northern Ecuador, and the Lobb specimen may well have been collected in southern Colombia.

Psammisia sp.

"Lobb 89, near Pilispi, 5,000 ft., New Granada."

This also represents a new unpublished species of Mr. Smith's, and no other material is referable to it. The locality is probably in southern Colombia or northern Ecuador.

Cavendishia, indeterminable

"Lobb 83, Columbia" on specimen. Mr. Smith states that although the material is too incomplete for identification, it resembles species from southern Colombia, and probably is from that region.

"Thibaudiae"

"Lobb 79, woods Rosario, 5,000 ft., Columbia."

This is the type of a species in an unpublished genus of Mr. Smith's. In the "List of Dried Specimens" the locality for this number is given as "Woods Rosario, Pro. Cuenca Ecuador, 5,000 ft." and the two other references to this place on the list are also associated with the Province of Cuenca. This is direct evidence of "Columbia" having been written on a sheet bearing an Ecuadorean collection.

BORAGINACEAE

Cordia curassavica (Jacq.) R. & S.

"Lobb 50, Columbia" written on specimen.

This is the only Lobb specimen in material of *Cordia* from western South America sent me by Kew for examination. It is certainly *C. curassavica*, a Caribbean species common along the north coast of South America, extending south in Colombia only a comparatively short distance up the Magdalena Valley, and wholly unknown from the mountains of southwestern Colombia, Ecuador, and Peru. If the specimen actually was collected by Lobb, he doubtless obtained it at some northern Colombian port while traveling between Panama and England.

Heliotropium incanum R. & P.

"Lobb 97, Columbia" written on sheet.

Otherwise this species is known only from central and southern Peru, where it is common. In his paper on the South American species of *Heliotropium* Johnston cites [11] this specimen under the general heading Peru.

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[11] Contr. Gray Herb. **81**: 41. 1928.

COMPOSITAE

Eupatorium diplodictyon Robinson

" Lobb, Columbia " written on sheet.

This is the type of the species, and has never since been discovered in Colombia, though J. F. Macbride recently collected the plant near Muña, in central Peru (no. 4296). Doctor Robinson has briefly discussed [12] these dubious " Colombia " collections of Lobb's.

CONCLUSIONS

The material here presented covers doubtless only a small fraction of the Lobb Colombian specimens cited in literature and a smaller fraction of those in the Kew herbarium, but the following conclusions apparently may safely be drawn:

1. That Lobb made a collection, probably a small one, in the present Department of Nariño, in southwestern Colombia, and that these specimens represented characteristic species of that region.

2. That he collected a few plants at a northern port of Colombia probably Cartagena or Santa Marta.

3. That he made large collections in southern Ecuador and smaller collections in central and northern Ecuador, and that a great majority of these sheets are labeled erroneously " Columbia," a few, perhaps, " Peru."

4. That he collected extensively in the mountains of central Peru, many of these sheets being labeled " Columbia."

5. That botanists should view with suspicion all " Lobb, Columbia " citations in literature or inscriptions on herbarium sheets, and should hesitate before ascribing any extraordinary range of distribution to a species solely on the basis of these " Lobb, Columbia " specimens.

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[12] Contr. Gray Herb. **77**: 14. 1926.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 87, NUMBER 2

A MIOCENE LONG-BEAKED PORPOISE FROM CALIFORNIA

(WITH FOUR PLATES)

BY
REMINGTON KELLOGG
Assistant Curator, Division of Mammals, U. S. National Museum

(PUBLICATION 3135)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
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A MIOCENE LONG-BEAKED PORPOISE FROM CALIFORNIA

By REMINGTON KELLOGG

ASSISTANT CURATOR, DIVISION OF MAMMALS, U. S. NATIONAL MUSEUM

(With Four Plates)

The fossil porpoise described in this paper was presented to the United States National Museum by G. M. Cunningham of the Standard Oil Company of California, Bakersfield, Calif. This skull unquestionably represents an undescribed species of one of the long-beaked porpoises. Its closest affinities appear to be with the Patagonian Lower Miocene genus *Argyrocetus* to which it is tentatively referred.

ARGYROCETUS JOAQUINENSIS new species

Type.—U.S.N.M. No. 11996. An incomplete skull, lacking the major portion of the rostrum, the superior border and right half of supraoccipital, the hinder outer border of right supraorbital process, the upper portion of right exoccipital, the right zygomatic process with exception of postglenoid portion, the tympanic bullae and periotics on both sides, and all of the teeth with the exception of one crown.

Type locality.—About 12 miles northeast of Bakersfield and 1,000 feet west of Pyramid Hill, in sec. 14, T. 28 S., R. 29 E., Kern County, Calif.; shown on Caliente Quadrangle, United States Geological Survey.

Horizon.—This skull was embedded in a fine-grained calcareous sandstone nodule, which was found about 75 feet below the top of the Vedder zone during May, 1930, by Max Steineke of the Standard Oil Company of California. The following invertebrate fossils were obtained at the same locality and identified by William F. Barbat: *Pecten bowersi* Arnold, *Pecten perrini* Arnold, *Ostrea titan* Conrad, *Cardium vaqueroensis* Arnold, *Spisula granti* Wiedey, *Dosinia margaritana* Wiedey, *Phacoides sanctaecrucis* Arnold, and *Chione* indet. The sands of the Vedder zone[1] lie about 1,400 feet

[1] Wilhelm, V. H., and Saunders, L. W., Report on the Mt. Poso oil field. Summary of operations California oil fields. 12th Ann. Rep. State Oil and Gas Supervisor, California State Min. Bur., San Francisco, vol. 12, no. 7, pp. 6, 8-9, January, 1927.

below the top of the Temblor formation; the Vedder zone has a maximum thickness of 85 feet in the Mount Poso area and underlying these sands are 550 to 650 feet of marine sediments, making a total thickness of 2,000 to 2,100 feet. The Vedder horizon, according to G. M. Cunningham, is older than the Barker's ranch locality which has been described by F. M. Anderson.[1] It is the opinion of Mr. Barbat that this horizon should be correlated with the Vaqueros formation which is thought to be equivalent in time with the Burdigalian [=Langhian] stage of the European Tertiary.

DIAGNOSIS

As compared with *Argyrocetus patagonicus* Lydekker,[2] this species is characterized by an elevated vertex formed for the most part by the elongated nasals and the hinder ends of the thickened premaxillaries, the mesorostral gutter is narrower, and the hamular processes of the pterygoids are conspicuously prolonged backward. It agrees with *A. patagonicus* in having a broad, concave ∩ shaped supraoccipital shield, in having the outer borders of the maxillaries at the base of the rostrum slope downward, and in having the vertex contracted antero-posteriorly.

SKULL

Dorsal view.—Although the major portion of the rostrum is destroyed it is obvious that this skull belongs to one of the long-beaked porpoises. The dorsal surface of the skull is constituted almost entirely by the maxillaries and the premaxillaries; the hinder extremities of the premaxillaries, the nasals, and the small wedgelike bone (presumably frontal) form the vertex of the skull. The maxillary notches are well marked. From the dorsal aspect the maxillaries are seen to increase in width from the broken extremity of the rostrum posteriorly. When they reach the level of the maxillary notches the maxillaries are thrust backward over the supraorbital processes of the frontals and expanded laterally to form the so-called frontal plates. These thin plates of the maxillaries and the corresponding underlying lateral extensions of the frontals roof over the temporal

[1] Anderson, F. M., The Neocene deposits of Kern River, California, and the Temblor basin. Proc. California Acad. Sci., ser. 4, vol. 3, pp. 98-100, November 9, 1911.

[2] Lydekker, R. Contributions to a knowledge of the fossil vertebrates of Argentina. Pt. II. Cetacean skulls from Patagonia. Anal. Mus. La Plata, vol. 2 for 1893, pp. 10-12, pl. 5, figs. 1, 1a, 2, 3, 1894.

fossae. The maxillary does not entirely sheathe the preorbital angle of the supraorbital process. The hinder margins of the left maxillary are probably imperfect above the temporal fossae. The dorsal surface of the left maxillary is depressed opposite the nasals and slightly convex above the supraorbital processes of the frontals. The internal margin of the maxillary, with the exception of the narrow tongue-like portion, which overlaps the frontals on the vertex, is in contact with the premaxillary for practically its entire length. Two foramina, which are connected with the infraorbital canal, are present on each maxillary. The most posterior one of these is situated above the temporal fossa. The other foramen is located at or near the level of the maxillary notch and from it a deep groove extends forward for a distance of at least 20 mm. The outer border of the maxillary at the base of the rostrum is not bent upward as in *Eurhinodelphis,* but is curved obliquely downward. In correlation with this tapering of the rostrum the maxillary decreases in breadth anteriorly and the sides become more nearly vertical. Anterior to the maxillary notches the premaxillaries are fairly thick and their upper surfaces are convex. Their inner margins become closely approximated at a point 130 mm. in front of the maxillary notches. The raised outer convex portions of the premaxillaries diverge strongly between this point and the maxillary notches, and constitute the outer border of the more or less flattened internal portions of the premaxillaries. In consequence of their tapering, these elevated outer convex surfaces disappear in front of the presphenoid. The premaxillaries commence to expand horizontally in front of the nasal bones and attain their maximum width at the level of the anterior walls of the narial passages. Opposite the narial passages there is an oval concavity on each premaxillary. The posterior end of each premaxillary is relatively broad, conspicuously thickened, and its dorsal surface is raised to the level of the nasals. The premaxillary foramina are moderately large and are situated behind the level of the anterior maxillary foramina. Each of these premaxillary foramina opens into a broad groove, which is continued obliquely backward and outward to a point opposite the narial passages. The internal border of the premaxillary, which is somewhat flattened in front of the presphenoid, narrows rapidly and finally disappears anteriorly under the raised convex outer strip. The premaxillaries do not approximate each other as closely in front of the narial passages as in *Eurhinodelphis bossi* from the Calvert formation of Maryland and hence the mesorostral gutter is not roofed over for a distance of 160-175 mm. Proximally, the floor of the mesorostral gutter is contributed by the premaxillaries and the vomer.

The apex of the mesethmoid rises to the level of the dorsal surfaces of the premaxillaries. The mesethmoid sheathes the dorsal and lateral faces of the presphenoid and thus forms a partition between the narial passages superiorly, fills in the frontal fontanelle, and provides support for the nasals, and also for the vertex of the skull. The anterior narrowing of the narial passages is correlated with the distal enlargement of the presphenoid. Notwithstanding the horizontal expansion of the premaxillaries, most of the anterior end of the presphenoid is exposed. The presphenoid is the porous bone that forms a plug across the proximal end of the mesorostral gutter, but does not rise to the level of the premaxillaries above.

The frontals are largely hidden from a dorsal view, being overspread by the premaxillaries and maxillaries laterally and by the nasals medially. Posteriorly the frontals abut against the supraoccipital on the vertex and it is barely possible that a very narrow strip of these bones may have been exposed between the hinder ends of the nasals and the missing dorsal crest of the supraoccipital.

The elongated nasals are relatively large (35 x 16.5 mm.) and are placed on the vertex between the posterior extremities of the premaxillaries, but do not overhang the narial passages. The anterior border of each nasal is bevelled off obliquely. The hinder ends of the nasal bones are unusually thick (pl. 3). Behind the right nasal and nearly in the midline, there is a small wedge-shaped bone which may be either an exposed portion of the right frontal or a fortuitous division of the right nasal.

Lateral view.—Aside from the relatively large size of the braincase, the skull (pl. 2) is characterized by a rather high temporal fossa which is partially roofed over by the maxillary and the underlying lateral extension of the frontal, a fairly wide orbit, and a long zygomatic process. The rostrum is somewhat depressed proximally and compressed from side to side anteriorly.

The orbit is strongly convex, the outer margin of the supraorbital process of the frontal being thickened, while the superimposed plate of the maxillary is thin and shelving. The preorbital portion of the supraorbital process of the frontal is rounded, while the postorbital angle is almost trihedral. The small lacrimal is closely appressed to the preorbital angle of the supraorbital process and its inner end is mortised into the under surface of the maxillary. The jugal is a very slender bone whose anterior end is ankylosed with the lacrimal below the maxillary notch and whose styliform process is extended backward beneath the orbit to the anteroventral angle of the zygomatic process where it is expanded into a broad thin plate. The jugal was unavoidably removed while the skull was being freed from the matrix.

The zygomatic process of the squamosal is thickened dorsoventrally and is almost in contact anteriorly with the postorbital angle of the supraorbital process. As a whole the zygoma is robust, slightly curved, and rather long; the dorsal profile slopes gradually forward and upward. The postglenoid portion of the zygoma curves downward and then forward. The greatest length of the left zygoma is 90 mm. and the dorso-ventral diameter anteriorly is 18 mm.

The crest formed by the contact of the supraoccipital with the hinder ends of the frontals is destroyed but it was presumably the highest point in the dorsal profile. The dorsal profile of the skull slopes rather steeply from the vertex to the level of the maxillary notches. On each side of the vertex, the frontal plate of the maxillary is depressed. The supraorbital process of the frontal and the superimposed maxillary do not rise above the level of the premaxillary in front of the narial passages. The temporal fossa is much longer than the orbit. In the temporal fossa the parietal is suturally united inferiorly with the squamosal, anteriorly and superiorly with the frontal, and posteriorly with the supraoccipital. Hence the parietals are excluded from the vertex of the skull. When viewed from the side, the occipital condyles are seen to project considerably beyond the level of the hinder surfaces of the exoccipitals. The basicranial axis is bent downward from the axis of the rostrum.

Posterior view.—This surface (pl. 3) attains its greatest breadth at the level of the exoccipitals. These exoccipitals are relatively large, are coalesced with the supraoccipital above, and are projected outward and backward like wings. Their external margins are sinuous-rounded, and are produced outward so that they conceal for the most part the postglenoid processes when viewed from behind. Anteriorly the exoccipital is in contact with the squamosal and inferiorly it is united with the basioccipital. The suture between the exoccipital and the basioccipital lies internal to the deep jugular incisure and the former constitutes the hinder border of the falcate process of the latter. At the bottom of this incisure and near the posterior margin there is a small condylar foramen. Externally the upper portion of the exoccipital is produced backward, forming a crest which follows the curvature of the hinder end of the temporal fossa. This thinedged crest is continuous with the corresponding portion of the supraoccipital and together they form a prominent lambdoid crest. The dorsal contour of the supraoccipital is uncertain since this portion of the lambdoid crest has been destroyed. Between the upper limits of the temporal fossae the supraoccipital is deeply concave. The greatest breadth of the supraoccipital is about equivalent to its vertical diameter above the foramen magnum.

The foramen magnum is sub-oval in outline; its transverse diameter is 35 mm. and its vertical diameter 24 mm. The occipital condyles are considerably broader near the apex than near the base, and their articular surfaces curve outward and forward. Their internal faces converge inferiorly and have a sharp hinder edge. The external margins of the occipital condyles are convex and are not set off from the exoccipitals by distinct necks. The outer border of the left condyle has been damaged and the entire articular surface of the right condyle is missing. Below the occipital condyles and internal to the exoccipitals are the descending plates of the basioccipital and they in turn are separated from the large paroccipital processes by the deep jugular incisures.

Ventral view.—Near the base of the rostrum the ventral surfaces of the maxillaries are closely approximated and the keel of the vomer is entirely concealed.

The lacrimal is closely appressed to the anterior face of the supraorbital process of the frontal and its internal end is mortised into the ventral face of the maxillary; the anterior end of the jugal is ankylosed with the lacrimal below the maxillary notch. Inasmuch as no suture can be found it should be stated that these three bones constitute the lower margin of the maxillary notch.

The jugal is a long, slender bone consisting of a short triangular enlarged anterior portion ankylosed with the lacrimal, and a styliform posterior process. The posterior end of the styliform process is dorso-ventrally flattened and extremely thin, being loosely attached to the ventral face of the zygomatic process. The jugal was unavoidably removed during the preparation of this specimen.

There is nothing peculiar about the position of the palatines. They are suturally united medially in front and are closely appressed to the under surfaces of the maxillaries. Viewed from the side, the palatine extends forward beyond the level of the maxillary notch and projects backward above the external reduplication of the pterygoid to the anterior margin of the optic canal. Close to its posterior extremity, the palatine presumably comes in contact with the orbitosphenoid which lies above it.

The relations of the pterygoids with the surrounding bones is essentially in agreement with that of *Eurhinodelphis bossi.* The external reduplication of the pterygoid is for the most part destroyed. Remnants of the ends of the outer plate on the left side show that the internal and external plates of the pterygoids are separated from each other by a narrow interval anteriorly, but posteriorly they are widely separated. Hence the usual pterygoid sinus must have been present. The curved internal plate contributes the lower outer surface for the narial passage. The combined internal and external plates of the pterygoid seemingly contribute to the formation of the elongated, backwardly projecting hamular process which constitutes a posterior extension of the palatal surface. The anterior margin of the external plate of the pterygoid is united by an irregular suture with the palatine. The external plate of the pterygoid is suturally united with the squamosal and palatine, and apparently is in contact with the parietal and alisphenoid.

The outer wall of the cranium in the region of the alisphenoid and orbitosphenoid is imperfect. The optic canal, while seemingly confluent with the sphenorbital fissure, nevertheless has its course marked by a definite groove. This canal should be bounded anteriorly near its origin by the descending portion of the orbitosphenoid.

A recess is formed by the backward extension of the alisphenoid (Pl. 4) and the contiguous underlying lateral process of the basioccipital, which completely excludes the periotic and tympanic from the inner wall of the cranium. On the roof of this recess and near its posterior end is a large orifice that corresponds to the *foramen lacerum posterius* for the nerves associated with the jugular leash.

The thin descending plates or falcate processes of the basioccipital are directed downward and outward; anteriorly they are suturally united with the internal plates of the pterygoids which overlap the basisphenoid.

The distinguishing features of the squamosal are the large size and strength of the zygomatic arch, the short robust postglenoid process, and the thin falciform process which is directed forward and downward in front of the tympano-periotic recess. The zygoma is rather large and is directed slightly outward. The ventral glenoid surface is an oval concavity, looking forward, inward, and downward. A narrow groove for the external auditory meatus traverses the squamosal behind the postglenoid process. The hinder end of the squamosal is suturally united with the exoccipital and between this suture and the transverse groove for the external auditory meatus a rounded tuberosity is formed. Internal to the glenoid fossa and on the ventral surface of the squamosal there is a longitudinal depression, deeper posteriorly than anteriorly. This depression commences at the base of the inner face of the postglenoid process and extends forward to the anterior or temporal margin of the squamosal. The ventral portion of the squamosal, internal to this last-mentioned fossa, is prolonged downward and inward to form a thin plate which, when complete, is suturally united with the external reduplication of the pterygoid.

The paroccipital process is relatively thick, its ventral aspect is roughened, and internally in conjunction with the descending plate of the basioccipital an incisure is formed for the passage of the so-called jugular leash and associated nerves.

REMARKS

Porpoises with long slender rostra predominated in the pelagic faunas of the Lower Miocene, as is evidenced by the occurrence of *Argyrocetus* in Patagonia, and *Ziphiodelphis, Schizodelphis* [=*Cyrtodelphis*], *Eoplatanista*, and *Acrodelphis* in Italy. The two last-mentioned genera are sufficiently distinct from the California skull to eliminate them from further consideration.

Although the proportions of this skull (Pl. 1) and the relations of the bones constituting the dorsal surface are strongly suggestive, at first glance, of *Eurhinodelphis longirostris*[1] from the Upper Miocene Anversian stage of the Antwerp Basin, Belgium, there are some well-marked differences. The skull from California has a smaller orbit, a longer and more slender zygomatic process, a relatively greater transverse diameter at the level of the preorbital angles of the supraorbital processes, the zygomatic width is somewhat less, the hinder extremities of the premaxillaries are greatly thickened and are applied to the lateral surfaces of the elongate nasals, the supraoccipital shield is strongly concave, and the occipital condyles are less protuberant. The nasals are missing on the type skull of *E. longirostris* (No. 3249, Mus. Roy. Hist. Nat. Belgique, Bruxelles) and the elements marked *N* on Abel's plate (1902, Pl. 11) are actually the frontals, into which the nasals were mortised. It is certain, however, that *E. longirostris* has much wider nasals than the California porpoise. The braincase of *Argyrocetus joaquinensis* is somewhat

[1] Abel, O., Les dauphins longirostres du Boldérien (Miocène supérieur) des environs d'Anvers. Pt. II. Mém. Mus. Roy. Hist. Nat. Belgique, Bruxelles, vol. 2, pl. 11, 1902.

narrower at the level of the supraorbital processes than that of *Eurhinodelphis bossi*[1] from the Upper Miocene Calvert formation of Maryland, and the construction of the vertex is quite different. In *E. bossi*, which is approximately the same size as *A. joaquinensis*, the nasal bones are quite small, the area of both nasals being somewhat less than the exposed portions of the combined frontals on the vertex, and the thin outer border of the maxillary at the base of the rostrum is bent upward.

The genus *Eurhinodelphis* is not known to occur in Lower Miocene deposits. There are, however, three related genera that are characteristic of this geological stage. The long-beaked porpoise, *Ziphiodelphis abeli*,[2] from the Lower Miocene Langhian sandstone quarries of Bolzano, Italy, has the vertex similarly contracted in an antero-posterior direction, the transverse diameter of the nasals being almost twice the antero-posterior diameter, the exposed portion of the combined frontals on the vertex is approximately equivalent in area to that of the two nasals, and a small interparietal is present. The supraoccipital shield is nearly vertical and flattened transversely, the rather thin outer borders of the maxillaries are bent upward at the base of the rostrum, and the hinder extremities of the premaxillaries are not conspicuously thickened. The teeth, however, have the roots markedly enlarged below the base of the enamel crown, but are rapidly attenuated toward the extremity. This genus seems to have its closest affinities with *Eurhinodelphis*.

As regards *Schizodelphis sulcatus* from marine sediments belonging to the Lower Miocene Langhian stage at Gauderndorf near Eggenburg, Austria,[3] and also from the Langhian sandstone quarries at Belluno in Upper Italy,[4] the nasals are quite small, the frontals com-

[1] Kellogg, R., On the occurrence of remains of fossil porpoises of the genus *Eurhinodelphis* in North America. Proc. U. S. Nat. Mus., vol. 66, art. 26, pp. 1-40, pls. 17, 1925.

[2] Dal Piaz, G., Sui vertebrati delle arenarie Mioceniche di Belluno. Atti Accad. sci. veneto-trentino-istriana, Padova, Cl. I, Anno V, pp. 13-16, figs. 5-7, 1908; Basani, F., and Misuri, A. Sopra un Delfinorinco del calcare Miocenico di Lecce (Ziphiodelphis abeli Dal Piaz). Mém. R. Accad. Lincei Cl. sci. fis. mat. e nat., Roma (5), vol. 9, fasc. 2, pp. 25-38, pl. 1, fig. 6, 1912; Dal Piaz, G., L'Istituto geologico dell' Università di Padova nel 1922. Notizie Sommarie. Mém. Ist. Geol. R. Univ. di Padova, vol. 6, p. 11, fig. 6, 1922.

[3] Abel, O., Untersuchungen über fossilen Platanistiden des Wiener Beckens. Denkschr. k. Akad. Wiss. math.-naturw. Kl., Wien, vol. 68, pp. 839-874, pls. 1-4, 1899.

[4] Dal Piaz, G., Sugli avanzi di Cyrtodelphis culcatus dell'arenaria di Belluno. Pt. I. Palaeontographia Italica, Pisa, vol. 9, pp. 187-220, pls. 28-31, text figs. 16, 1903.

prise the major portion of the large vertex, the area of the exposed portions of the frontals on the vertex being considerably larger than that of the two nasals, a small interparietal is present, the zygomatic process is relatively short and robust, and the roots of the teeth are shaped somewhat like a heraldic battle axe. In so far as our present knowledge goes the proportions, relations, and structural peculiarities of the several elements entering into the composition of the braincase and rostrum of *Schizodelphis* are sufficiently pronounced to eliminate this genus from consideration.

The long-beaked porpoise, *Argyrocetus patagonicus*,[1] from the Lower Miocene Patagonian marine formation at Castillo, opposite Trelew, on the coast of Chubut Territory, Argentine Republic, resembles this California skull somewhat, for the vertex is contracted antero-posteriorly and the backward rostral thrust has carried the maxillary to the supraoccipital, but the two nasals are about equivalent in area to that of the exposed portions of the frontals on the vertex and the mesorostral gutter is relatively wide. This skull, unfortunately, is imperfectly preserved, both zygomatic processes being incomplete, the supraorbital processes are broken off, and the hinder ends of the premaxillaries are missing. The shape of the supraoccipital shield, the elevation of the vertex, and the proportions of the skull of *Argyrocetus patagonicus* approximate in the main the skull from California. These resemblances seem to warrant the tentative allocation of the California skull to the genus *Argyrocetus*, though this is done with considerable hesitation, since the material upon which both species are based is quite fragmentary.

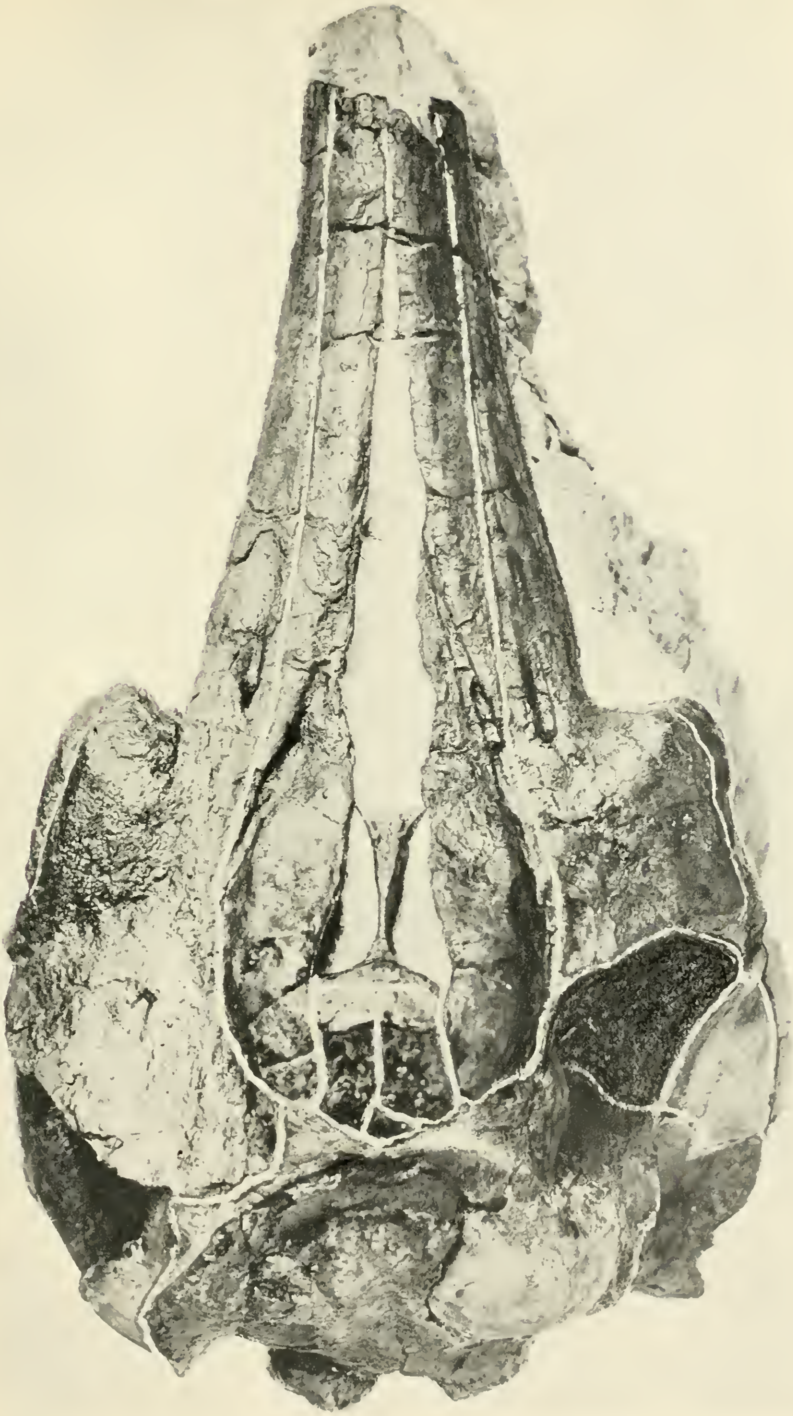
TEETH

The crown of a single tooth, presumably from the right maxillary, is embedded in the matrix 12 mm. in front of the broken extremity of the rostrum. The crown of this tooth is lanceolate in outline, it curves outward and then inward, and is flattened transversely. The anterior and posterior margins of the crown are rounded and not carinate, and the enamel is essentially smooth. The hinder end of the maxillary tooth row lies 60 mm. in front of the maxillary notch.

[1] Lydekker, R., Contributions to a knowledge of the fossil vertebrates of Argentina. Pt. II. Cetacean skulls from Patagonia. Anal. Mus. La Plata, vol. 2 for 1893, pp. 10-12, pl. 5, figs. 1, 1a, 2, 3, 1894.

Measurements of the skull (in millimeters)

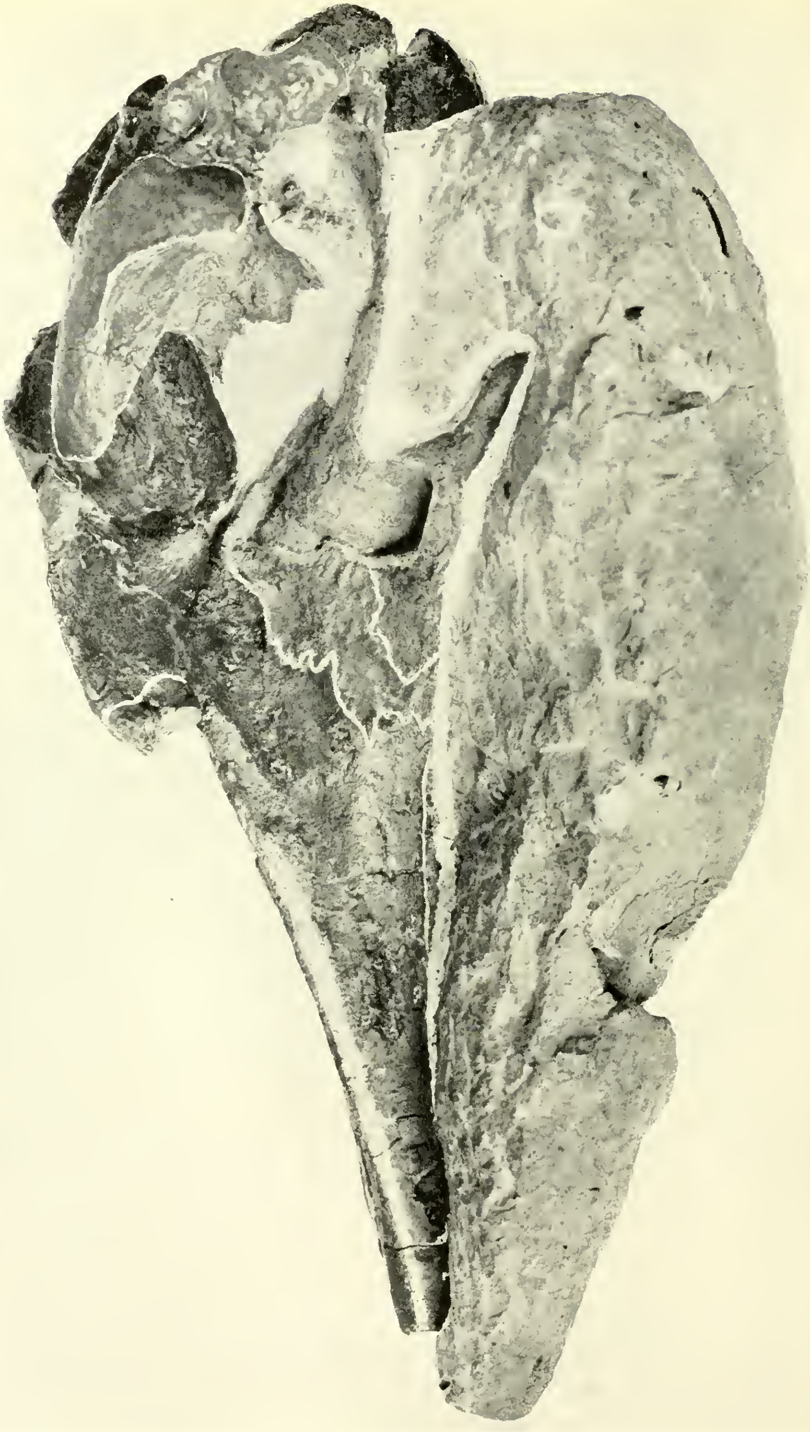
Total length, as preserved	370
Transverse diameter of skull across preorbital angles of supraorbital processes of frontals	176
Transverse diameter of skull across postero-external angles of supraorbital processes of frontals	204±
Distance across skull between outer surfaces of zygomatic processes	210±
Distance across skull between outer margins of exoccipital bones	178+
Distance between inner margin of left occipital condyle and outer margin of left exoccipital	72
Distance between outer angles of paroccipital processes	167
Distance between outer surfaces of descending processes of basioccipital	98
Distance between outer margins of occipital condyles	74
Greatest or oblique-vertical diameter of left occipital condyle	44
Maximum transverse diameter of left occipital condyle	33
Transverse diameter of foramen magnum	35
Vertical diameter of foramen magnum	24
Distance from upper margin of foramen magnum to apex of supraoccipital shield	105+
Vertical distance from basioccipital to apex of supraoccipital shield	116+
Distance from ventral face of hamular process of pterygoid to dorsal surface of nasal bone	156
Greatest vertical depth of skull at level of anterior borders of narial passages	87
Greatest vertical depth of rostrum at level of maxillary notches	57
Greatest vertical depth of rostrum at broken extremity (165 mm. in front of maxillary notches)	35
Preorbital angle of left supraorbital process to posterior face of left occipital condyle	215
Greatest distance between outside margins of premaxillaries at level of narial passages	85
Greatest breadth of left premaxillary at level of anterior border of narial passages	33.5
Greatest breadth of left premaxillary at level of maxillary notch	21
Breadth of rostrum at level of maxillary notches	108
Greatest antero-posterior diameter of left supraorbital process of frontal	83
Antero-posterior diameter of left nasal along suture	35
Transverse diameter of left nasal, anteriorly	16.5
Greatest length of left zygomatic process	90
Width of braincase 10 mm. below squamosal-parietal suture in temporal fossae	122



Argyrocetus joaquinensis new species. Type.
Dorsal view of skull. About one-half natural size.

Argyrocetus joaquinensis new species. Type.
Lateral view of skull. About one-half natural size.

Argyrocetus joaquinensis new species. Type.
Posterior view of skull. About one-half natural size.



Argyrocetus joaquinensis new species. Type.
Oblique view of ventral surface of skull. About one-half natural size.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 87, NUMBER 3

SETH EASTMAN: THE MASTER PAINTER OF THE NORTH AMERICAN INDIAN

(WITH 15 PLATES)

BY
DAVID I. BUSHNELL, JR.

(PUBLICATION 3136)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
APRIL 11, 1932

SETH EASTMAN, 1808-1875

Self-portrait about 1829, now owned by his granddaughter, Miss A. H. Eastman, Washington, D. C.

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SETH EASTMAN: THE MASTER PAINTER OF THE NORTH AMERICAN INDIAN

(With 15 Plates)

BY
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(With 15 Plates)

Seth Eastman was born in Brunswick, Me., January 24, 1808, and died in Washington, D. C., August 31, 1875. He was appointed to the Military Academy, West Point, from Maine and entered as a cadet July 1, 1824. He was graduated and became a second lieutenant in the First Infantry July 1, 1829.

Eastman appears to have possessed much natural talent for drawing and painting, but there are neither records nor family traditions of his having received instruction in sketching or portrait painting before he entered the Academy. A small self portrait in oil, reproduced as Plate 1, was made at about the time of his graduation and reveals his ability at that time. The approximate date of the picture may be determined by the fact that only one epaulet is shown, worn on the left shoulder. The army regulations of 1825 specified: "Captains of Engineers, one gold Epaulette on the right shoulder, and Subalterns one on the left." By the regulations of 1832 lieutenants, or subalterns, were required to wear two epaulets. Therefore the portrait was necessarily made between the date of his graduation, 1829, and the year 1832.

Eastman's career as an artist may be divided into two distinct periods. The first and more important extended from the time he left the Academy as a second lieutenant until the winter of 1849-1850, when he reached Washington; on February 27, 1850, he was instructed to prepare illustrations for Schoolcraft's great work. His military record during these 20 years, as preserved in the Adjutant General's Office, War Department, Washington, D. C., is as follows:

"On duty at Fort Crawford, Wisconsin, with regiment, 1829-1830, and at Fort Snelling, Minnesota, 1830-1831; on topographical duty 1831 to January 9, 1833; Assistant Teacher of Drawing, United States Military Academy, to January 22, 1840; in the Florida War 1840-1841; with regiment at Fort Snelling, Minnesota, from 1841 to 1846; on recruiting service in 1846; at Fort Snelling, with regiment, 1846 to 1848; on march through Texas to San Antonio, Fredericksburg, and the Neuces River, 1848-1849."

During these 20 years Eastman made innumerable paintings and sketches of the Indians with whom he came in contact, and scenes in the Indian country, including the games, ceremonies, and activities witnessed in and about the native villages and camps. Many of the pencil sketches, remarkable in themselves, served the artist in later years, when they were reproduced in oil on canvas. The sketches were prepared with the greatest care, dated, described, and often signed, thus proving the training for detail which he had received at the Academy.

The two army posts where the young lieutenant was destined to spend his first years of active service after leaving the Military Academy were frontier posts in the heart of the Indian country. Both were frequented by several tribes possessing different manners and customs. Such surroundings afforded a young and enthusiastic artist many opportunities to sketch and study the various ceremonies performed by the Indians who visited the posts, or whose camps and villages were nearby. Many details of their primitive ways of life were maintained, and these, fortunately, were often the subjects of the artist's sketches.

Fort Crawford was the first post to which Eastman was sent during the late summer or early autumn of 1829. It stood a few miles above the mouth of the Wisconsin River, near the left bank of the Mississippi, on the low ground, Prairie du Chien, which had been a gathering place for the native tribes for many generations—long before it was traversed by Europeans. A pencil drawing of the fort, an early example of the artist's work, is reproduced in Plate 2. This bears the legend " Fort Crawford, Prairie du Chien, 537 miles above St. Louis, Oct. 1829." The houses of the village of Prairie du Chien appear on the right.

Father Marquette reached the Mississippi by descending the Wisconsin River, June 17, 1673, and evidently the region soon became well known to the French traders and trappers. Here, about the middle of October, 1766, came an English army officer, and in his narrative printed a few years later he mentioned a large Indian village [1] " on the bank of the Mississippi, near the mouth of the Ouisconsin, at a place called by the French La Prairies les Chien, which signifies the Dog Plains ; is a large town, and contains about three hundred families ; the houses are well built after the Indian manner. . . . . This town is a great mart, where all the adjacent tribes, and even those who inhabit the most remote branches of the Mississippi, annually assemble about the latter end of May, bringing with them their furs to dispose of to the traders."

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[1] Carver, J., Travels through the interior parts of North America, in the years 1766, 1767, and 1768, p. 50. London, 1779.

PENCIL DRAWING. "FORT CRAWFORD—PRAIRIE DU CHIEN, 537 MILES ABOVE ST. LOUIS, OCT. 1829."

David I. Bushnell, Jr.

Size 25 by 35 inches

"SQUAWS PLAYING BALL ON THE PRAIRIE."

David I. Bushnell, Jr.

Soon after Carver's visit a group of French, coming from Canada, established the village of Prairie du Chien. A garrison was maintained in the vicinity for many years, but not until the year 1816 was the construction of a fort begun. A year later, on July 25, 1817, Maj. Stephen H. Long was at the post when returning from the Falls of Saint Anthony, and that day entered in his journal:[1] "Spent the day in measuring and planning Fort Crawford and its buildings. The work is a square of 340 feet upon each side; and is constructed entirely of wood, as are all its buildings, except the magazine, which is of stone, it will accommodate five companies of soldiers."

Fort Crawford, with the nearby French village of Prairie du Chien, soon became an important center, a gathering place where several tribes received their annuities and conducted their trade with the Fur Company. The tribes who visited the post were the Menominee, Winnebago, and Fox, then occupying lands east of the Mississippi, as well as some of the Siouan tribes from farther up the Mississippi. A small Menominee settlement stood near Fort Crawford in 1831 which was the scene of a serious attack by some of the tribal enemies. About this time Schoolcraft visited the fort and wrote:[2]

"While at Prairie du Chien, the murder of 26 Monomonee men, women, and children, by a war party of the Sacs and Foxes, which had transpired a few days previous, was the subject of exciting interest. It was narrated with all its atrocious circumstances. A flag waved over the common grave of the slain, and several of the wounded Monomonees, who has escaped the massacre, were examined and conversed with. This affray, unparalled for its boldness and turpitude, having occurred in the village of Prairie du Chien, in the hearing of its inhabitants, and in sight of the fort, was made the subject of demand by the government for surrendry of the murderers, and produced the concentration of troops on that frontier, which eventuated the Indian war of 1832."

It is believed the picture of "Squaws Playing Ball on the Prairie," a photograph of which is reproduced in Plate 3, represents a group of Menominee, and possibly members of another tribe, in the vicinity of Fort Crawford, and that it was sketched while Eastman was stationed at that post, 1829-1830. This would have been during the year preceding the massacre mentioned by Schoolcraft. The level prairie is clearly shown, with the river in the distance and the hills beyond. The

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[1] Long, Maj. Stephen H., Voyage in a six-oared skiff to the Falls of Saint Anthony in 1817. Coll. Minnesota Hist. Soc., vol. 2, pt. 1, p. 56, 1860.

[2] Schoolcraft, Henry R., Narrative of an expedition through the Upper Mississippi to Itasca Lake, p. 13. New York, 1834.

smoky atmosphere and browned grass proves that it was a scene witnessed late in the autumn, and suggests Indian summer, that most delightful season of the year in the northern valley. This painting was one of six purchased from the artist by the American Art Union in 1849. It bore the number 169 in the catalogue that year and was distributed with others December 21, 1849. It is a work of great beauty and interest, and is believed to be one of Eastman's earliest Indian pictures.

Others had witnessed and mentioned the game being played at, or rather on, Prairie du Chien. Pike reached the village April 18, 1806, and two days later, Sunday, April 20, held a council with Winnebago chiefs, and that same afternoon, so he wrote in his journal:[1] "they had a great game of the cross on the prairie, between the Sioux on the one side, and the Puants and Reynards on the other. The ball is made of some hard substance and covered with leather, the cross sticks are round and net work, with handles of three feet long. . . . . In the game which I witnessed, the Sioux were victorious, more I believe, from the superiority of their skill in throwing the ball than by their swiftness, for I thought the Puants and Reynards the swiftest runners." The great chief Wabasha was present at the gathering and consequently the Sioux who that day played against the Winnebago and Fox were probably of his band, who had come down the Mississippi from their village on Wabasha Prairie, mentioned by many who passed up and down the river during succeeding years. But it remained for Catlin to leave the most interesting account of a game of ball played by women on the level ground at Prairie du Chien. This was witnessed during the summer of 1835, about five years after Eastman was stationed at Fort Crawford. Catlin was at the post when, so he wrote:[2] "Wa-be-sha's band of the Sioux came there, and remained several weeks to get their annuities." A day came when the men "wanted a little more amusement, and felt disposed to indulge the weaker sex in a little recreation also; it was announced amongst them, and through the village, that the women were going to have a ball-play!

"For this purpose the men, in their very liberal trades they were making, and filling their canoes with goods delivered to them on a year's credit, laid out a great quantity of ribbons and calicoes with other presents well adapted to the wants and desires of the women; which were hung on a pole resting on crotches, and guarded by an old

[1] Pike, Maj. Z. M., An account of expeditions to the sources of the Mississippi, and through the western parts of Louisiana, p. 100. Philadelphia, 1810.

[2] Catlin, George, Letters and notes on the manners, customs, and condition of the North American Indians. London, 1841.

man, who was to judge and umpire the play which was to take place among the women, who were divided into two equal parties, and were to play a desperate game of ball, for the valuable stakes that were hanging before them."

Catlin's original painting of the game witnessed by him and described in the preceding quotation, is now in the collection of the United States National Museum, Washington. It reveals many details similar to those shown in Eastman's painting believed to have been sketched at the same place a few years before. Both represent the level area bordered by the river with hills beyond, groups of Indians gathered to witness the play, and the stakes " which were hung on a pole resting on crotches," to be awarded to the winners of the game.

In 1835 Catlin wrote: " Praires du Chien is the concentrating place of the Winnebagoes and Menomonies, who inhabit the waters of the Ouisconsin and Fox rivers, and the chief part of the country lying east of the Mississippi and west of Green Bay."

FORT SNELLING

Fort Snelling or, as it was originally named, Fort Saint Anthony, was the second army post to which Lieutenant Eastman was assigned with the First Infantry. This was in 1830 and it is evident he went direct from Fort Crawford, up the Mississippi to the mouth of the Saint Peters. Several sketches in one of his sketch books, showing views along the river, are believed to have been made at that time.

Fort Snelling occupies the summit of a high cliff at the junction of the Mississippi and Minnesota rivers, the latter formerly known as the Saint Peters. This prominent point is on the left bank of the Minnesota and right bank of the Mississippi, and was visited and described by Pike in 1806. Eleven years later, in 1817, Major Long recommended the establishment of an army post at the confluence of the streams. Lieutenant Colonel Leavenworth, with a detachment of the Fifth Infantry, arrived at the mouth of the Saint Peters River September 17, 1819, and " on the 10th of September, 1820, the cornerstone of Fort St. Anthony was laid. The barracks were at first log structures." [1] Col. Josiah Snelling arrived at the post and relieved Leavenworth about the beginning of September, 1820. Later the name of the new commander was applied to the fort.

The young lieutenant did not remain long at Fort Snelling at this time and from 1831 to January 9, 1833, was " on topographical duty,"

[1] Neill, Rev. E. D., Occurrences in and around Fort Snelling from 1819 to 1840. Coll. Minnesota Hist. Soc., 1865.

but it is not known what part of the country he visited. From this latter date to January 22, 1840, he served as assistant teacher of drawing at the Military Academy, West Point. During these years he made many paintings and sketches, scenes in the vicinity of the Academy and many of the historic spots along the banks of the Hudson. He exhibited in the exhibitions of the National Academy of Design in 1836, 1837, 1838, 1839, and 1840. In 1838 he included two paintings of Fort Snelling, both then owned by Army officers, the original sketches for which had undoubtedly been made in 1830 or 1831, when he was first stationed at that post.

Eastman was elected an honorary member of the National Academy of Design in 1838, while still at West Point. He had one painting in the exhibition of 1848 which was described as " Indian Burial." There are no examples of Eastman's work at the Military Academy although he made many paintings and sketches during the years he was stationed there as teacher of drawing.

AMONG THE SEMINOLES IN FLORIDA

As already stated, Lieutenant Eastman's assignment as assistant teacher of drawing at the Academy terminated January 22, 1840, and from West Point he went south to join his regiment. According to the army records he was " in the Florida War, 1840-1841," but just where he was stationed is not known. A brief sketch of events in Florida shortly preceding Eastman's arrival on the peninsula will be of interest in connection with one of his water-color drawings which is now reproduced.

Maj. Gen. Alexander Macomb, Commanding in Chief of the Army, left Washington March 22, 1839, " for Garey's Ferry, on Black Creek in Florida," where he arrived April 5. His endeavor was to make peace with the Seminoles. Runners were sent throughout the country to acquaint the scattered Indians with his arrival in their country and to request them to gather in council at Fort King, but not until after the middle of the following month did he meet with a degree of success. " Lieutenant Colonel Harney, accompanied by Chitto Tustanuggee, the great war chief of the tribes associated with Apiaka, attended by Ochi-Hajo, a brother of Blue Snake, arrived from Cape Florida the day before the council. . . . . The next day (the 18th) the council was accordingly held." [1]

[1] Report of the Major General Commanding the Army. Ex. Doc. No. 2. House of Repr. 26th Cong., 1st Sess., Washington, 1839.

Later that same day, after the Indians had met the Army officers in council, General Macomb issued the following General Orders:

HEAD QUARTERS OF THE ARMY OF THE UNITED STATES
Fort King, Florida, May 18, 1839.

The Major General, commanding in chief, has the satisfaction of announcing to the army in Florida, to the authorities of the Territory, and to the citizens generally, that he has this day terminated the war with the Seminole Indians by an agreement entered into with Chitto-Tustenuggee, principal chief of the Seminoles and successor to Arpeika, commonly called Sam Jones, brought to this post by Lieutenant Colonel Harney, 2d Dragoons, from the southern parts of the peninsula. . . . .

ALEXANDER MACOMB
Major General Commanding.[1]

The report of peace proved premature, and through treachery on the part of the Indians quiet was not restored for many months. But the document served to identify Sam Jones as the great chief of the Seminoles, Chitto Tustenuggee, whose name frequently occurs in reports and narratives connected with the war.

Fortunately, Captain Eastman visited the southern part of Florida and, as would be supposed, made sketches with pencil and water color. One of the latter is a view of " Sam Jones' Village," which reveals a group of shelters, for the most part roofs of palmetto thatch supported by upright posts set in the ground. These primitive structures are surrounded by semitropical vegetation, with open water in the distance. A large wooden mortar and pestle are shown in the extreme lower right corner of the sketch, with a very large snake on the left. The exact location is not known, but it was undoubtedly far south on the peninsula. This extremely interesting picture is reproduced in Plate 4.

AT FORT SNELLING

With the exception of a short period during the year 1846 when he was " on recruiting service," Captain Eastman was stationed at Fort Snelling with his regiment from 1841 to the autumn of 1848 when he went to Texas. During the years he served at the post he made innumerable sketches of the Indians who frequented the fort, then in the heart of the region dominated by the Mdewakanton, a tribe of the Dakota, the largest division of the Siouan linguistic family. The native villages stood on the banks of the Mississippi and Minnesota rivers, easily reached from the fort.

Maj. Lawrence Taliaferro had served as Indian Agent at Fort Snelling for many years and resigned at the close of 1839. His last

[1] Giddins, Joshua R., The Florida exiles. New York, 1863.

report was dated "Northwestern Agency, St. Peter's, Iowa Territory, September 30, 1839," and in it he gave a valuable account of the several tribes of the Dakota, with many of whom he was personally acquainted. Concerning the "Medawakantons," occupying the country surrounding Fort Snelling, he said in part: "This tribe numbers exactly 1,658 souls; 484 warriors, 406 women, and 768 children of all ages. These reside in seven detached villages, composed of bark houses; and in winter, buffalo, elk, or other skin lodges are resorted to during their migration or hunting expeditions." These were the people with whom Eastman came in contact and were the subjects frequently sketched and painted. But parties of the Ojibway, who claimed and occupied the country north and east of the Mississippi, likewise visited the post, and often members of the two groups, ever enemies, met in the vicinity of the fort and engaged in combat which usually resulted in the death or wounding of some.

Two important villages of the Mdewakanton, "mystery lake village," of the Santee or eastern division of the Dakota, were then standing a short distance from Fort Snelling. Kaposia, the more extensive and better known, was on the right bank of the Mississippi about 12 miles below the mouth of the Saint Peters, or Minnesota River, as the stream was later designated. Little Crow was chief and the village was visited and briefly described by many who ascended the river. Both the bark-covered lodge, in form not unlike that of a log cabin but having the entrance at the end instead of side, and conical skin tipi were to have been seen at the settlement, with an ancient burial ground and many scaffold burials on the summit of the cliff which bordered the low ground over which the habitations were scattered. It is believed that many of Eastman's pictures were sketched at Kaposia. The second of the native villages belonged to another band of the Mdewakanton and was usually known as "Shakopee's Village," from the name of the chief whose home it was. This settlement stood on the banks of the Minnesota River, some miles above its junction with the Mississippi, in the present Scott County, Minn.

Far down the Mississippi, about 140 miles below the mouth of the Minnesota River, was the important village of Wapasha, on the right bank of the river, occupying part of "Wahbasha's Prairie," now within the bounds of Winona County, Minn. The name Wabasha, "the red leaf," was applied to a long line of chiefs of the Mdewakanton, long before they had been driven from the shores of Mille Lac and forced to seek a new home on the banks of the Mississippi, when they established the most southern village of their tribe, the first to be encountered when ascending the river.

Size 8 by 7⅞ inches 1841

"SAM JONES' VILLAGE IN FLORIDA."

Mrs. M. M. Forrest

Size 15 by $11\frac{3}{4}$ inches 1844

ETA KEAZAH—SISSETON SIOUX AT FORT SNELLING

David I. Bushnell, Jr.

Such then was the Indian Country in the midst of which the artist remained some years. A region of lakes and streams, forests and prairies, and where wild game abounded. Amidst these primitive surroundings Eastman made many sketches, but very few belonging to the years before 1847 have been traced. One portrait, made at Fort Snelling in 1844, is reproduced in Plate 5. This is in oil, on a panel of wood, and is a likeness of a Sisseton Sioux named Eta Keazah. It shows the use of the beaded head covering worn by the northern Indians, both Sioux and Ojibway, during the winter season; however, caps of this sort were used extensively throughout the northern country as far east as the tribes of New Brunswick and Nova Scotia. Eastman shows them worn by Indians fishing through the ice, in one of his later paintings.

It is to be regretted that Eastman failed to keep a journal during his stay in the Indian country, for had he made notes of events that transpired at the army posts and of the gatherings of the Indians, and described the individuals and the native villages, his writings would have proved of value equal to that of his sketches and paintings.

The year 1848 may be regarded as the most interesting period of Eastman's career as an artist, and possibly he anticipated his early removal from the post and departure from the upper Mississippi, and therefore made many sketches in the vicinity of Fort Snelling which served him in the following years when he was preparing the illustrations for Schoolcraft's work.

While still on the upper Mississippi, during the month of July, 1848, he witnessed a stirring event on "Wahbasha's Prairie," about 150 miles below the Falls of Saint Anthony, below Lake Pepin, on the right bank of the Mississippi. This excitement was occasioned by a band of Winnebago at the time of their removal, and may best be explained by quoting from the official documents of the time:

St. Peter's (Winnebago) Agency

October 4, 1848

Sir: Since my last annual report of the condition of the Winnebago Indians, the most important event connected with them is their removal from the neutral ground to the country they now occupy. When the tribe was notified last spring, by the government, that their new home was procured for them, they decided at once to remove, and such arrangements were made as would have enabled them to remove comfortably, and with a very moderate expense, but the interference of interested individuals created dissatisfaction and disturbance among the Indians, which caused much delay, and resulted in scattering one-half of the tribe. Some of those who turned back went to their old hunting ground in

Wisconsin, others went west into the interior and western part of Iowa. I have recently been informed that a party of about one hundred in number have joined the Ottoes, southwest of the Missouri river. . . . .

J. E. Fletcher,
Indian Agent.[1]

The report of the Commissioner of Indian Affairs dated November 30, 1848, contains a brief reference to the removal of the Winnebago: "The experiment in the case of the Winnebagoes has also been successful; although their emigration from Iowa to their new country on the upper Mississippi was attended with some delay and difficulty; caused, however, by the unauthorized interference of interested white persons, and of a portion of the Sioux that were desirous to have them stop and remain in their country."

It was evidently Wabasha's band of Mdewakanton Sioux that desired the Winnebago to settle or remain with them, and the exciting scene witnessed by Captain Eastman was probably enacted at that time. The pencil drawing, described by the artist as: "Wahbasha's Prairie, Miss. River. Scene in July 1848. Difficulty with the Winnebagoes while removing them to their present country," now reproduced in Plate 6, is a beautiful example of his work and reveals his great skill in showing minute detail. The United States troops are drawn up on the left with a large number of mounted Indians, probably the Winnebago, in their front. The small group of armed Indians, crouching on the river bank in the immediate foreground, appear to be operating with the Americans.

In a letter written from "Fort Snelling, I. T., August 6, 1848" and signed "S. Eastman, *Captain* 1st *Infantry, Commanding Fort Snelling*" he discussed "means as will effectually stop the Indians from smuggling ardent spirits into the country." The letter was addressed to Maj. Thomas H. Harvey, Superintendent of Indian Affairs, but no means were ever effective. As Eastman was at that time in command at Fort Snelling he may have led the troops shown facing the Winnebago on "Wahbasha's Prairie."

Later in the year Captain Eastman again visited "Wahbasha's Prairie," and made an interesting sketch of a group of temporary shelters, probably a camp of a small number of Indians. This bears the legend: "Miss. River. Wahbasha's Prairie. 725 miles above St. Louis—looking South. Oct. 1848" (pl. 7).

The Territory of Minnesota was created in 1849. On May 16 of that year one who was ascending the Mississippi entered in his narrative: "passed Wapasha's Prairie . . . . a beautiful prairie in Min-

[1] Ex. Doc. no. 1, 30th Cong., 2d Sess., Washington, 1848.

PENCIL DRAWING. "WAHBASHA'S PRAIRIE, MISS. RIVER. SCENE IN JULY 1848."

David I. Bushnell, Jr.

Pencil Drawing. "Wahbasha's Prairie, 725 miles above St. Louis, looking south, Oct. 1848."

David I. Bushnell, Jr.

nesota, about nine miles long and three miles wide, occupied by the chief Wapasha (or Red-Leaf) and his band of Sioux, whose bark lodges are seen at the upper end of the prairie." And that same day, after leaving Lake Pepin, "an Indian village, called Red Wing, inhabited by a tribe of Sioux is seen on the Minnesota shore. It appears to contain about one dozen bark lodges, and half as many conical lodges, covered with buffalo skins; also, a log or frame house, occupied by a missionary. Indian children were seen running, in frolicsome mood, over the green prairie, and Indian females were paddling their canoes along the shore. This village is near the mouth of Cannon River."[1] The next day, May 17, he passed Kaposia, then consisting of some 40 skin lodges and having a population of about 300.

Such were the native villages along the banks of the Mississippi in Minnesota just before the organization of the State.

The small water color reproduced in Plate 8 is believed to have been made on the bank of the Minnesota River, above Fort Snelling, and may be a sketch of Shakopee's village. It is signed and dated 1848 and was probably made just before Eastman was detached from Fort Snelling. Some beautiful pencil drawings made about this time are also reproduced, one being entitled: "Sioux Indians Playing the Game of the Plum Stones" (pl. 9), which was later engraved, and "Buffalo Hunt of the Sioux Indians" (pl. 10), in which the artist recorded the use of the spear, bow and arrow, and gun, by the mounted hunters.

The report of the Indian Agent, dated "Saint Peters Indian Agency, Sept. 15, 1847," refers to the condition of the Sioux as "more favorable the past year. Buffalo, about the head of St. Peters River, have been much more abundant than usual, which is to be accounted for by the fact that prairies farther north were burned over, so that these animals were driven to seek subsistence in a more southern region." This may have enabled Captain Eastman to have witnessed the hunting of the buffalo by the Indians nearer Fort Snelling than formerly, and some of his sketches were possibly made at that time.

As already mentioned, many of the pencil sketches that Eastman made during the years he was stationed at Fort Snelling were copied and worked up in after years when he had returned to Washington. Two examples are shown in Plate 11, illustrating two phases of the process of dressing a deer skin, which he had undoubtedly witnessed

[1] Seymour, E. S., Sketches of Minnesota. New York, 1850.

in the vicinity of the post. The two pictures are entirely different. Figure 1, a water-color sketch, dated 1850 and consequently made in Washington, is copied from a small pencil drawing; Figure 2 is a photograph of a large oil painting, now hanging in a room of the House Committee on Indian Affairs in the Capitol Building, Washington, D. C. The latter was painted in 1868 or 1869 and will again be mentioned. The two pictures serve to illustrate a passage in one of the publications of the artist's wife:[1]

"When the animal is killed . . . . the women take off the hair of the skin with a knife, after which they moisten the skin, and stretch it to upright poles . . . . or on the ground, by means of pegs driven in the earth. When there are white people near to whom they can apply, they try to obtain a little soap to cleanse the skin; but if dependent on themselves, they use, in the place of soap, the brains of the animal. These they spread over the skin, scraping it with an iron or bone scraper. Thus they remove all the fat and greasy particles. They then rub the skin against a cord that is stretched to a couple of stakes, until it has become soft. The work is completed when the skin is smoked. To accomplish this, a hole is dug, and a small fire built at the bottom. Over the hole a few sticks are laid. Across these they place the skin. The hole is covered with leaves or turf, to confine the smoke as much as possible, and to smother the flame. After the skin is smoked from ten to twenty hours, it becomes of a dingy, yellowish color, and is ready for use."

Although the foregoing reference is to buffalo skin, it is believed that all skins were tanned in the same manner and that the description would apply equally well to deer skin.

Skins of the buffalo thus prepared served many purposes, and were most important in the life of the Indian, especially of the plains tribes. They were used in making moccasins and coarse garments such as shirts and leggings, and a number of them sewed together and properly shaped formed the covering for the tipi. The hide is very harsh, rough, and quite porous and could never be dressed so fine and soft as were the skins of deer and other animals.

CAPTAIN EASTMAN AND THE AMERICAN ART UNION

The American Art Union, known during the first five years of its existence as The Apollo Association, was organized in 1838 and continued until 1852. It was created for "the promotion of the Fine

[1] Eastman, Mrs. Mary H., The American aboriginal port folio. Philadelphia. [1853].

1848

Size 5¼ by 8½ inches

SIOUX ENCAMPMENT, PROBABLY SHAKOPEE'S VILLAGE

Miss A. H. Eastman

PENCIL DRAWING. "SIOUX INDIANS PLAYING THE GAME OF PLUM STONES."

David I. Bushnell, Jr.

PENCIL DRAWING. "BUFFALO HUNT OF THE SIOUX INDIANS."

David I. Bushnell, Jr.

Size 8 by 6½ inches 1850

1. INDIAN WOMAN PREPARING A SKIN

David I. Bushnell, Jr.

Size 39 by 29 inches 1868

2. INDIAN WOMAN DRESSING A DEER SKIN

House Committee on Indian Affairs, Capitol Building

Arts in the United States," and the money derived from the dues paid by the members was used to purchase the works of American artists which were then distributed to the members by lot each year at the time of the annual meeting. This manner of disposing of the many paintings, engravings, medals, and other objects, was declared by the New York Supreme Court on October 22, 1852, " illegal and unconstitutional," and led to the dissolution of the organization.

The American Art Union during its few years undoubtedly did a great deal to assist the young artists of the country, and the names of many who became well known in later years are to be found on the lists appearing in the publications of the Union. The first annual meeting was held December 16, 1839, at which time 63 paintings were distributed among the members, but the number steadily increased and on December 22, 1848, 454 paintings were won by the members; the number distributed on December 21, 1849, was 460.

The name of Seth Eastman first appeared in 1848, the last year he was stationed in the upper Mississippi valley. That year the Art Union purchased six of his paintings, all Indian subjects, but unfortunately neither description nor dimension is given in connection with the reference to the pictures which appeared in the Bulletin issued by the Union that year. The six paintings purchased during the year 1848 were:

No. 288. Indian Burial.
No. 333. Indian Scalp Dance.
No. 334. Buffalo Hunt.
No. 441. Moonlight—Sioux Landing.
No. 448. Sioux Breaking up Camp.
No. 449. Dog Dance—a Dance of the Braves.

The next year, 1849, the Art Union again purchased six pictures, likewise Indian subjects, all of which were briefly though interestingly described in the Bulletin as follows:

61\. Sioux in Council. (25 by 35 inches.)
" These figures are all painted from life, and are portraits. An old chief is lecturing a young warrior for cowardice."

71\. O-ho-ka-pe, an Indian Hunter. (25 by 35 inches.)
" This is a celebrated hunter of the Sioux nation. He is said to have killed thirteen deer in one day. During the last war with Great Britain he was captured by the English, and kept in prison several months, at which time he lost his intellect. This was taken from life by Capt. Eastman."

72\. Sississiton Chief. (25 by 35 inches.)
" This is also a portrait. The original is called 'The Burning Earth.' He resides near the headwaters of the St. Peters River, and is chief of a band of Dacotahs."

167. Medicine Dance. Dacotah or Sioux Indians. (25 by 35 inches.)
"A large party of Indians beside their wigwams, engaged in the mystic ceremonies of the medicine dance."

169. Squaws Playing Ball on the Prairie. (25 by 35 inches.)
"A large number are engaged in this exercise, running swiftly in opposing bands, while others in the foreground are looking on."

171. Buffalo Hunt. (25 by 35 inches.)
"A herd of buffaloes are attacked by Indians, one of whom has been dismounted by a furious bull, which his comrade dispatches with a lance."

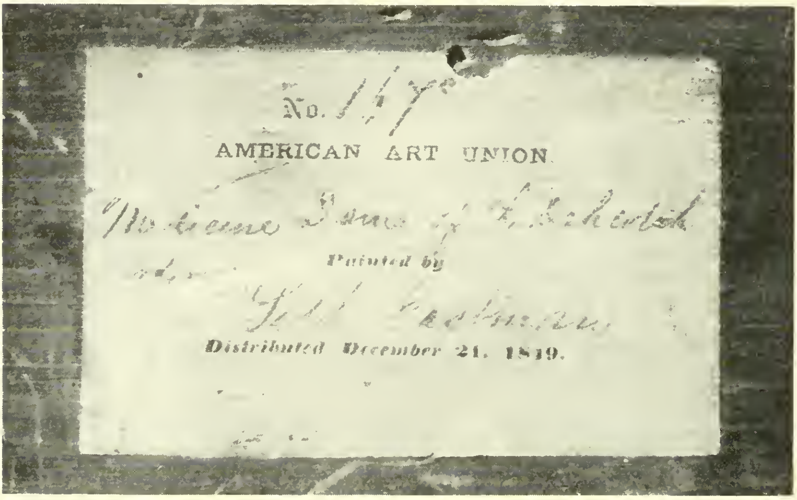

Fig. 1.—Label attached to the stretcher of the painting reproduced in Plate 12.

Again in 1850 Eastman disposed of the same number of pictures to the Art Union, but all were not Indian subjects, three being of a different nature. The three pictures of interest at this time were thus described in the Bulletin:

149. Indian Hunters. (30 by 25 inches.)
"Two Indians—one seated, and holding a tomahawk; the other standing beside him, wrapped in his blanket."

155. Indians Playing Draughts. (30 by 25 inches.)
"Two are engaged at this game, which a third overlooks."

167. Indian Ball-Play. (25 by 35 inches.)
"A large number of Indians are engaged in this amusement upon the ice, beside which, among the trees, are seen the wigwams."

In 1851, the last year the Art Union purchased paintings, Captain Eastman disposed of one small picture entitled "Moonlight," evidently not an Indian subject.

Size 25 by 35 inches "MEDICINE DANCE OF THE DAHCOTAH OR SIOUX."

David I. Bushnell, Jr.

Size $5\frac{1}{4}$ by $8\frac{3}{4}$ inches December 1848

1. ALAMO AT SAN ANTONIO

Mrs. M. M. Forrest

Size $4\frac{3}{4}$ by 7 inches 1849

2. OLD MEXICAN LOOKOUT OR WATCH TOWER AT SAN ANTONIO, TEX. TWO MILES FROM THE ALAMO

Miss A. H. Eastman

Could the 15 paintings of Indian subjects which were acquired by the Art Union during the years 1848, 1849, and 1850 be assembled, they would form a collection of the greatest interest and importance, one not surpassed by the works of any other artist. But they are widely scattered, some are lost, and some may have been destroyed during the many years that have elapsed since they were distributed to members of the old organization. However, two are described at this time which serve to indicate what the others may have been.

The two paintings to which the preceding statement refers were distributed by the Art Union in December, 1849, and bore the numbers 167 and 169. The latter has already been described and illustrated in Plate 3. The second, number 167 in the Bulletin of the Art Union, December, 1849, is shown in Plate 12, and a photograph of the label attached to the stretcher is reproduced in Figure 1. It portrays the Medicine Dance of the Sioux and is believed to have been a scene witnessed by the artist at one of the several native villages which then stood not far from Fort Snelling. It is a most interesting example of Eastman's earlier work and was probably made at the post.

The Medicine Dance was one of the more important ceremonies of the Sioux, a very complete description of which was given some years ago by one who had undoubtedly seen it enacted in the vicinity of Fort Snelling. A brief quotation from the account will tend to make clear certain details of the painting. The superstitious beliefs of the people are first mentioned, with the traditional origin of the ceremony, and then it continues to describe it as enacted:[1]

"Early in the morning the tent, in form like that which the god first erected for the purposes, is thrown open for the dance. The members assemble painted and ornamented, each bearing his medicine-sack.

"After a few preliminary ceremonies, appropriate to the occasion, including a row of kettles of large dimensions, well filled and arranged over a fire at the entrance of the court, guarded by sentries appointed for the occasion, the candidate takes his place on a pile of blankets which he and his friends have contributed."

No two ceremonies would have been exactly the same, and this brief description is sufficiently clear to explain the scene as recorded on the canvas. On the left is a member, "painted and ornamented," carrying his medicine sack; on the extreme right is visible "a row of kettles of large dimensions," and near the center, resting upon blankets, is one who may be "the candidate." The large skin tipi,

[1] Pond, G. H., Dakota superstitions. Coll. Minnesota Hist. Soc., 1867.

opened and revealing a group of Indians with a drum, may have been considered "in form like that which the god first erected for the purposes."

IN TEXAS

About the beginning of October, 1848, Captain Eastman left Fort Snelling, where he had served so many years, and passed down the Mississippi to New Orleans. By the latter part of November he had arrived at San Antonio, but it is not known what route he had followed from Louisiana. He remained but a short time in San Antonio, then went some 65 miles north to Camp Houston, which had been established by the American forces near the town of Fredericksburg, where he remained until March 10, 1849.

While in and about San Antonio Captain Eastman made some very beautiful pencil and water-color sketches several of which are now reproduced. One small pencil sketch of the Alamo, dated November 22, 1848, bears this legend: "Front view of the Chapel in the Alamo, at San Antonio, Texas. David Crocket and 167 Texians were slain in this building by the Mexicans during the Texian Revolution." A few days later Eastman made the small water-color drawing which is now reproduced in Plate 13. This is signed with his initials and bears the date "Dec. 1848." Likewise on November 22, 1848, he made a pencil sketch of a ruined tower on which he wrote: "Old Mexican lookout or watch tower at San Antonio, Texas, Two miles from the Alamo." A water-color drawing was later made of the ruin, a photograph of which is reproduced in Plate 13, Figure 2. This is signed "S. Eastman, 1849." He also made a very beautiful pencil sketch of the "Mission Chapel of the Conception at San Antonio, Texas. Nov. 28, 1848," signed "S. Eastman, U. S. Army." These are of the greatest historical interest.

Sketches made in the vicinity of Camp Houston, near Fredericksburg, show the quaint structures which had been reared by the German settlers, and scenes in and near the village. The live oaks which attain great size at Fredericksburg and in the surrounding country, attracted much attention and were often sketched but, unfortunately, the artist evinced little interest in the few Indians with whom he came in contact.

Captain Eastman reached Washington during the winter of 1849-1850, where he remained more than five years preparing the numerous illustrations for Schoolcraft's work, "History, Conditions and Future Prospects of the Indian Tribes of the United States." For this purpose he made a great number of small water-color pictures,

1852

Size 26 by 36 inches

THE INDIAN COUNCIL

Painted for Peter Force

Size 32 by 45 inches 1869

1. INDIAN MODE OF TRAVELING

House Committee on Indian Affairs, Capitol Building

Size 32 by 45 inches 1868

2. SPEARING FISH IN WINTER

House Committee on Indian Affairs, Capitol Building many of which were copied from original sketches made during the preceding years spent in the Indian country, others were composed and drawn for reproduction by the engravers. But while engaged in making the illustrations for Schoolcraft's great work it is evident that Eastman painted other pictures of a more pretentious nature. One which he made in 1852 for his friend and neighbor, Peter Force, who then lived opposite the Eastman home on K Street, in Washington, is shown in Plate 14. This beautiful example of Eastman's work is now owned by descendants of the one for whom it was painted. It is called " The Indian Council," and although the grouping of the figures is quite similar to that of the painting made some years later for the Government, which is now hanging in the rooms of the House Committee on Indian Affairs, it differs in many details and is a more pleasing picture.

Having completed the Schoolcraft illustrations, Eastman served " with regiment at Forts Duncan and Chadbourne, Texas, 1855-1856." On October 31, 1856, he became a major and was attached to the Fifth Infantry; he was placed " on special duty in Quartermaster General's Office, Washington, D. C., 1857-1858."

Having returned to his home in Washington, he again became interested in his paintings and early sketches of scenes in the upper Mississippi valley, and in 1857 he painted the canvas entitled " Ball Play on the Prairies," which was purchased by W. W. Corcoran and now hangs in the Corcoran Gallery of Art, Washington, D. C.

Eastman became lieutenant colonel, 1st Infantry, September 9, 1861, and was retired December 3, 1863. He served in various capacities during the Civil War.

On March 26, 1867, Congress passed a joint resolution which enabled Eastman to paint the two groups of pictures which are owned by the government. This read in part: " It provides if the President shall deem it proper to assign Brevet Brigadier General Seth Eastman, of the United States Army, now on the retired list, to duty, so as to entitle him to full pay, emoluments, and allowances of his lineal rank. . . . ." The purpose of this was to have him execute paintings for the rooms " of the Committees on Indian Affairs and on Military Affairs of the Senate and House of Representatives," to be made from his own designs, the work to be done under the supervision of the architect of the Capitol. In addition to the picture of a woman dressing a deer skin, already mentioned (pl. 11), two other examples of his pictures painted for and now hanging in the rooms of the House Committee on Indian Affairs in the Capitol Building, are now reproduced (pl. 15, figs. 1 and 2).

The first is entitled " Indian Mode of Traveling," and shows a long line of Indians, some mounted, others on foot, crossing the prairie. The second is one of the most beautiful of his many paintings, and bears the title " Spearing Fish in Winter." This wintry scene was described by Mrs. Eastman in her book already mentioned, and to quote in part: " In the picture an Indian is about taking a fine fish from off his spear; the hatchet with which he broke the hole in the ice lies beside him.

" He is dressed in the warm dress worn by the Dacotas in the winter, his head protected from the cold by the cornered hood, which is only worn by the men. . . . ."

These were the artist's last Indian pictures. A few years later, while engaged on the series of forts, he was stricken and died in Washington, D. C., August 31, 1875.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 87, NUMBER 4

Research Corporation Fund

THE PERIODOMETER: AN INSTRUMENT FOR FINDING AND EVALUATING PERIODICITIES IN LONG SERIES OF OBSERVATIONS

(WITH ONE PLATE)

BY
C. G. ABBOT
Secretary, Smithsonian Institution

(PUBLICATION 3138)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
FEBRUARY 6, 1932

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In a paper entitled "Weather Dominated by Solar Changes,"[1] I described and illustrated a method of finding and evaluating periodicities by computation. My method consisted first in plotting the lengthy series of observational data on a large scale and scanning them from a distance in order to perceive tendencies, if any, toward a repetition of minima at some nearly regular interval.

Such an interval of 8 months seemed to appear in the plot of solar variation in the years 1924 to 1930. To test it and evaluate it, I arranged the 10-day mean solar-constant values in a table of 24 columns. The top line contained the values for the first 8 months, the second line those for the second 8 months, and so on until the data were exhausted. Mean values of the vertical columns were then taken. These indicated plainly the reality of the 8-month periodicity in solar variation, and determined the distribution of it. The mean form found for the curve of this periodicity did not approximate a sine curve, but showed a short quick rise from the minimum and a long slow decline from the maximum to the minimum.

The second step in computation was to subtract from the original data values representing the average march of the 8-month periodicity. A new curve of partial solar variation resulted, from which the average 8-month periodicity had been cleared. This residual curve was next scanned, and seemed to display an 11-month periodicity. It was evaluated and removed from the residual data in the same way that the 8-month periodicity had been evaluated and removed from the original data. The 11-month periodicity showed a double maximum and still less resembled a sine form than the 8-month periodicity.

A 45-month periodicity and a 25-month periodicity were similarly discovered, evaluated, and removed. In Figure 1, the residual curve *C*

[1] Smithsonian Misc. Coll., vol. 85, no. 1, 1931.

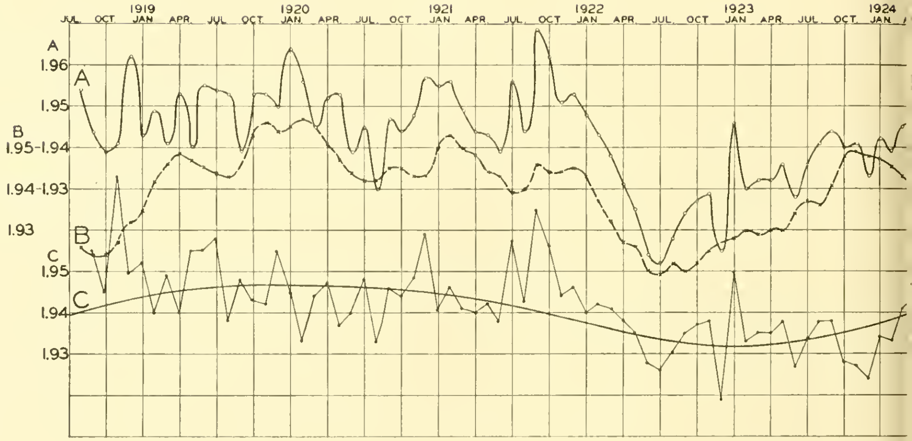
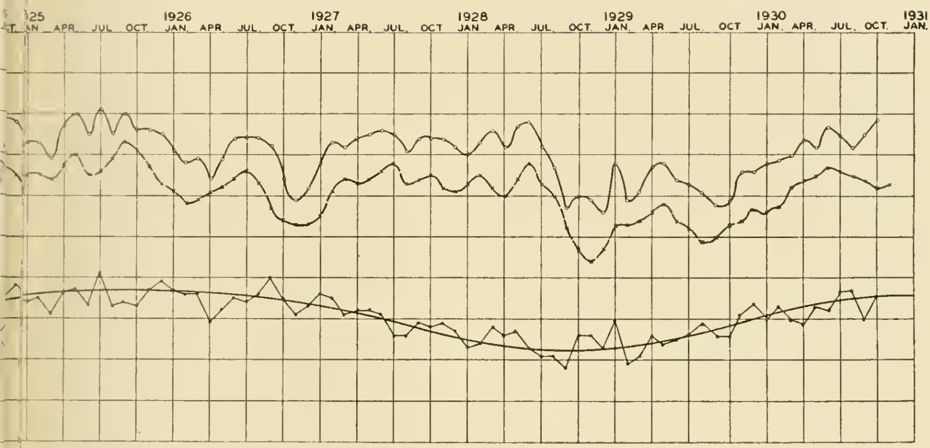


FIG. 1.—Monthly mean so



tins analysed for periodicity.

of solar variation, after thus evaluating and removing these four periodicities of 8, 11, 25, and 45 months, is compared with the original data shown in curve *A*. One other periodicity above 8 months appears conspicuously in curve *C*, namely, one of 68 months, as indicated by the smoothed curve. No other periodicity of importance remaining, the computation was concluded at that point. It had disclosed that the solar variation since 1918, as depicted by the march of monthly mean values, is adequately represented as the sum of five regular periodicities of 8, 11, 25, 45, and 68 months, whose sum is given in curve *B* of Figure 1. Curve *B* is drawn below curve *A* to avoid confusion, but will be seen to be a very close copy of curve *A*, except in the early years when the observations were least satisfactory.

I would like to emphasize that none of these five periodicities is of sine form, though the 68-month residual is not far from it. I would like also to remark that these five necessary and sufficient constituents of the solar variation since 1918 are not related to each other in length in the ratios $1 : \frac{1}{2} : \frac{1}{3} : \frac{1}{4} : \frac{1}{5}$ as would have been the periodicities used in Fourier analyses. It seems to me that the method which I have used leads more directly to true and significant relations than the arbitrary fitting of a curve by the classical methods based on Fourier analysis.

It occurred to me that the various steps used in computing might be done by a machine. Having suggested its design, I was so fortunate as to receive a grant of $1,000 from the Research Corporation of New York to aid in the construction. The work was done mainly by Mr. A. Kramer, instrument maker of the Smithsonian Astrophysical Observatory. Finding some difficulty, however, with the two large grooved barrels, each equipped with 152 sliders and a clamping device, these parts were very accurately made to my order by the Gaertner Scientific Corporation of Chicago.

Plate 1 gives a photograph of the completed instrument. A steel scale, *a*, with double graduation into millimeters and half millimeters, respectively, enables the observer to set up the data on the right-hand drum. This he does by rotating the knurled wheel, *b*, which, through gearing, engages a rack at *o*, on which is carried a vertical displaceable pawl. This pawl is adapted to engage successively the sliders, *d*, *d*, 152 in number, and push them along their grooves to proper settings, as measured by the scale, *a*. Check screw-clamps are provided to stop the rack at zero of the scale, *a*, on each return motion, whether to left as just indicated or to right as mentioned below. Thus a long curve, determined by the original data, is set up on the right-hand drum, and its sliders are clamped and fixed immovably by the screw and band, *e*, *e*. A small vice-clamp, *f*, operated by a knurled head now grasps one of the sliders on the left-hand drum. The vertical pawl used in pushing the sliders of the right-hand drum to their positions is now pushed by the rack and knurled wheel, *b*, until it touches the slider lying at the top of the right-hand drum. A train of gearing, *g*, *h*, variable through ratios $\frac{1}{5}$, $\frac{1}{4}$, $\frac{1}{3}$, and $\frac{1}{2}$ operates simultaneously a rack carrying the knurled head and its vise-clamp, *f*, and thereby pushes the front slider on the left-hand drum through $\frac{1}{5}$ (or other preferred fraction) of the travel of the pawl.

Returning to zero of the scale, *a*, the two drums are then moved forward one division by making a single rotation of the knurled wheel, *i*. The above process is repeated until as many sliders are set on the left-hand drum as there are data in the periodicity sought. Let us assume for illustration that these data number 8. Thus the individual values of this interval of 8 data are reproduced on $\frac{1}{5}$ scale on the left-hand drum. That drum is now reversed to its starting position, and a new series of 8 pushes is made. As these new pushes start from the positions already attained, we now have the average of the first 16 data reproduced on $\frac{2}{5}$ scale. Repeating the process until 40 data are covered, the left-hand drum then exhibits the mean value of the 8-datum periodicity over an interval of 40 data.

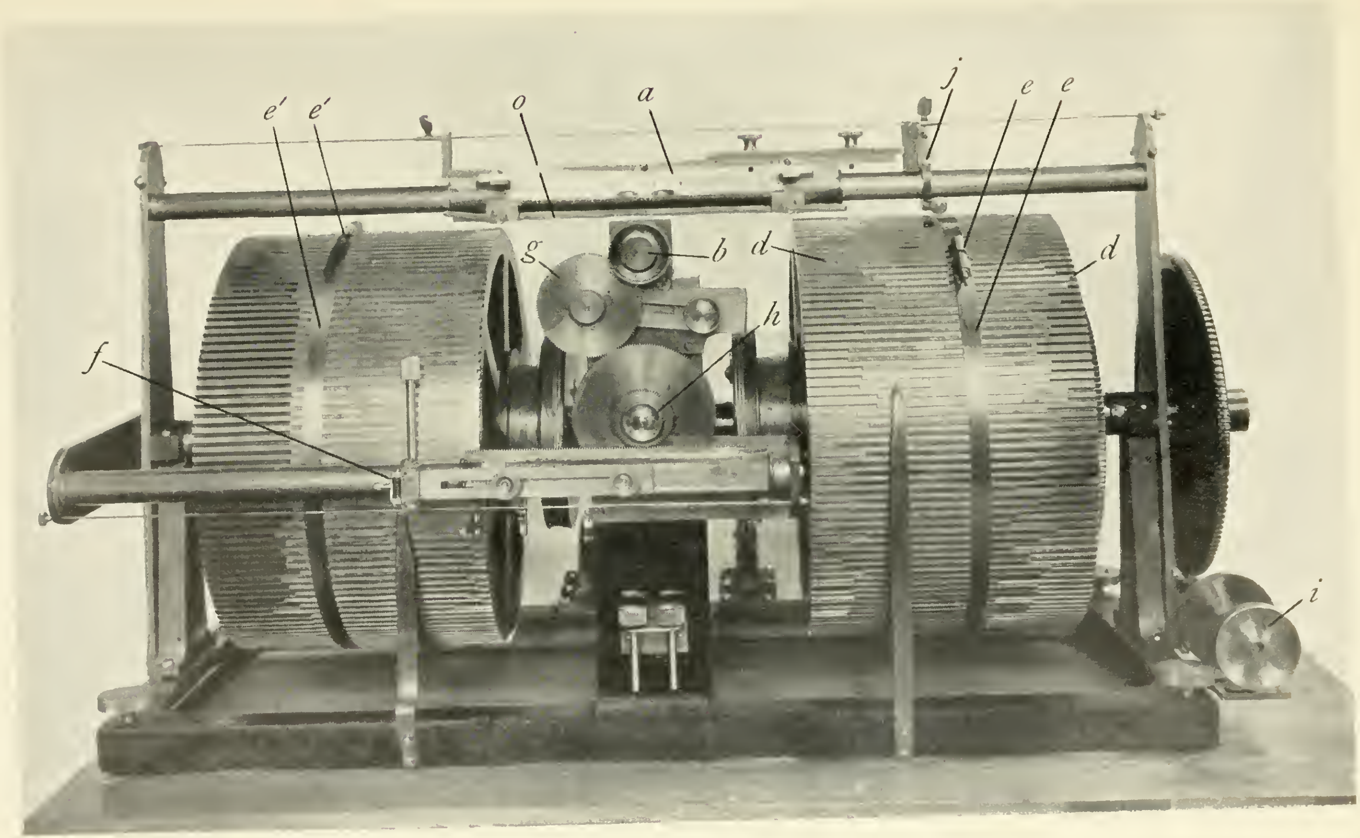
If the periodicity sought seems real, as revealed by the form of the mean curve thus determined, it may next be read off and recorded. Fresh data on the right-hand drum may then be used to give a second and a third determination of the 8-datum period. If these new determinations of it harmonize fairly with the first, then it is clear that the 8-datum period exists throughout the whole interval of the data. A mean of the three determinations is taken to represent it.

The general mean form of the 8-datum periodicity is next set up on the left-hand drum and clamped. The sliders of the right-hand drum are loosened. Then, employing the vise-clamp, *j*, and a second pawl available for the left-hand drum, all the sliders on the right-hand drum are moved toward the left through distances determined by the periodic setting of the sliders of the left-hand drum. This average 8-datum periodicity is used end to end successively so as to remove completely the average 8-datum periodicity from all the original data. Thus a residual curve remains, from which the average 8-datum periodicity has been eliminated.

The same procedure is repeated with any other periodicities which seem to be displayed by the settings of the sliders on the right-hand drum, until all promising possibilities are exhausted.

It is frequently desirable to take consecutive means of several data at a time in order to smooth a long series of observations. This is readily done with the periodometer. The original data are set up as usual on the right-hand drum. They are then all consecutively transferred to the left-hand drum on a scale of $\frac{1}{5}$, $\frac{1}{4}$, or accordant to any preferred smoothing grouping of five or less. The left-hand drum is then set back by the interval of one groove, and the transfer of all the data is made a second time. This process is repeated five times, four times, or to correspond with whatever consecutive grouping is chosen. The left-hand drum will then have set up upon it a curve on the same scale as the original curve, but smoothed by consecutive means. This curve may be read off and recorded or it may be transferred back to the right-hand drum as follows: Set the right-hand check screw-clamp corresponding to zero of the scale, *a,* and all the right-hand sliders at zero. Disconnect the gear train, *g, h,* and set the left-hand pawl as described above for eliminating evaluated periodicities. Turn the knurled wheel, *b,* towards the left till the pawl touches a slider, clamp the right-hand clamp, *j,* and turn back to zero of scale, *a*. Repeat for all the data of the smoothed curve, and the right-hand drum will then have upon it the smoothed curve set up ready for periodicity determinations.

As yet the periodometer has not been extensively used. It may be that after longer experience with it additional automatic features may be introduced which will promote speed of operation. In its present form it works well.



The Periodometer.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
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THE NARRATIVE OF A SOUTHERN CHEYENNE WOMAN

BY
TRUMAN MICHELSON
Ethnologist, Bureau of American Ethnology

(PUBLICATION 3140)

CITY OF WASHINGTON
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The following narrative was obtained for me by Mack Haag near Calumet, Okla., in the summer of 1931. I have corrected the English slightly, but otherwise the narrative is given as written out by Haag. I hereby express my warmest thanks.

A few ethnological notes, appearing as footnotes, are added as an aid to the comprehension of the text. These are not exhaustive and are confined for the most part to published Cheyenne sources. Incidentally they bear witness to the authenticity of the narrative.

NARRATIVE

My mother is 80 years old and is still living in apparently good health. If my father were living he would be about 85 years old. I do not remember in what year he died. My father's sister is also dead. She died when she was 102 years old. This aunt of mine was the person who instructed me in all the ways of courtship.[1]

I want to mention an incident that was later told me by my mother. She said that I was taught to ride horseback alone when I was 4 years old. Of course, I do not remember this.

Whenever they moved camp I was tied onto the saddle. One day, they say, I, or rather the pony, was lagging behind. My saddle girth became loose, and I and the saddle were under the horse's belly. Luckily the pony was very gentle.

When I became an older girl I was rather expert in riding horseback. This was my greatest sport. I even rode untamed ponies. Of course, sometimes I was thrown off by ponies who bucked very badly.

Ever since I can remember I had a bed of my own in my parents' tipi.[2] This bed consisted of willow head and foot uprights.[3] My own bags were placed against the wall of the tipi. The wall of the bed also included buffalo hides.[4] My pillows were decorated with porcupine

[1] I do not know whether or not instruction in courtship, etc., given by a paternal aunt to her niece is institutional.

[2] The beds ranged around the walls of a Cheyenne tipi: see Grinnell, George Bird. The Cheyenne Indians, vol. 1, p. 225. New Haven, 1923.

[3] Compare Grinnell, loc. cit., vol. 1, pp. 242, 243, vol. 2, p. 365.

[4] See Grinnell, loc. cit., vol. 1, p. 225.

quills.[1] My bed was always placed farthest from the door of the tipi, a place of honor.[2]

My mother taught me everything connected with the tipi, such as cooking and tanning hides for different purposes. The first pair of moccasins I made were for my father. "You are very good in making moccasins," he said with a smile, "they are very nice." This encouraged me greatly.

My mother would show me how to twist the sinews, and how to cut the soles and uppers of the moccasins for different sizes. I became very competent in this work at an early age. I used to make moccasins for other children, beaded as well as plain ones. I was always well rewarded for my work by the parents of the children.

Whenever we moved camp I always managed to catch my own riding pony, and to pack my personal belongings on another pony which was used for that purpose only.

My mother would always tell me that the main purpose of her teaching me, as well as the object of my owning my own bed, was to keep me at home, and to keep me from being away to spend my nights with my girl chum. This was done so that there would be no chance for gossip by other people.

My parents were very proud of me. In fact they treated me as if I were a male member of the family. They took the greatest pains to have me well dressed. Even my saddle was decorated. I also owned an elk-tooth dress.[3] This was afforded by only a very few. And it was by no means considered obtained by luck, but by years of hard hunting.

One day when we were moving, my mother taught me how to put a pack on the pony. This was a new pony unaccustomed to being packed. I noticed it would not stand still. When we turned it loose with the other pack animals it ran away and caused much excitement.

Apart from the regular training my mother gave me, she made for me the paraphernalia of the deer-hoof bone game, which are strung and looped at the end of a string.[4] The game is played by girls; and after maturity young men and young women participate in the game, sitting in alternate places. I was rather an expert in this game. I was always placed near the door. This was because I was a good player. In the alternate positions the young men were recognized as sweethearts whether they actually were or not.

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[1] For pillows decorated with porcupine quills see Grinnell, loc. cit., vol. 2, p. 186.

[2] See Grinnell, loc. cit., vol. 1, p. 73.

[3] See Grinnell, loc. cit., vol. 1, p. 224.

[4] See Culin, Stewart, Games of the North American Indians, 24th Ann. Rep. Bur. Amer. Ethnol., pp. 527 et seq., and 529-533, 1907.

In my girlhood days we girls played what we called "tiny play." This play imitated the customs and ways of the grown-up people. Our mothers made rag dolls of women, men, boys, girls, and babies. We used forked sticks to represent ponies, and we mounted the tiny people on the fork of the sticks, pretending to move camp. Sometimes a baby would be born; or, a marriage would take place—in fact anything that we knew about older people. In this play we did not allow any boys to play with us girls. We had rag dolls to represent boys.

After a time as I became a little older we played what we called "large play."[1] This play consisted of real people, namely, boys and girls. The boys would go out hunting (really, go to their tipis) and bring meat and other food. We girls would pitch our tipis and make ready everything as if it were a real camp life. Some of the boys would go on the warpath, and always came home victorious. They would relate their war experiences, telling how successful they were, especially with the Pawnee (Wolf Men). We girls would sing war songs to acknowledge the bravery of our heroes. Of course, we would have marriage feasts, dances, etc. Sometimes we had the Sun Dance.[2] In this play we did not use real food, but baked mud bread and used leaves for dishes. The pledger and the woman were there. We would have our children's ears pierced[3] and gave away horses. Some of the boys would have their breasts pierced with cactus thorns, others dragged buffalo skulls (which were really chunks of dead wood). Sometimes the older boys would come. When we saw them we always stopped and scattered. My aunt told me not to play with young men.

At one time—I remember the incident well—while we were playing with boys some young men came upon us. One of them took after me and seized the sleeve of my dress and tore it off. I surely was frightened, not that I feared bodily injury, but because I thought, "Here is a young man trying to bestow his manly attentions on me." It all seemed so strange and bewildering to me. Eventually this young man would come and see me, to court me.[4] At first I was very much

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[1] For a similar game among the Crow see Lowie, R., The material culture of the Crow Indians, Anthrop. Papers Amer. Mus. Nat. Hist., vol. 21, pt. 3, p. 249, 1922.

[2] On the Cheyenne Sun Dance see Dorsey, G. A., The Cheyenne, II. The Sun Dance, Field Columbian Mus. Pub. 103, Anthrop. Ser., vol. 9, no. 2, 1905; Grinnell, loc. cit., vol. 2, pp. 211 et seq.; Petter, R., English-Cheyenne Dictionary, article "Sun Dance," pp. 1028-1030, Kettle Falls, Wash., 1913-1915.

[3] For ear-piercing see Grinnell, loc. cit., vol. 1, pp. 61, 62, 105-107, 149; vol. 2, p. 276; Petter, loc. cit., p. 181 (article "bred").

[4] According to Grinnell the modern Cheyenne courtship is like that of the Sioux; see loc. cit., vol. 1, pp. 131 et seq.

afraid to venture outside after dark. I would always ask my mother to accompany me before I would go out. My mother furnished me rawhide twine and a piece of hide to use as a diaper which was securely tied around my hips and pudendum. This was done to preserve my virtue against the attacks of an overanxious young man.[1]

My aunt (father's sister) had heard that a certain young man had begun to look upon me seriously. She came over and began to tell me what to say and how to act in the presence of this young man. She said:

> I hear you are beginning to have admirers. Your father and mother have reared you with great care. Your father especially has seen to it that you have had good things to wear such as other girls of your age do not have. And your mother has taught you with great patience the art of things that each woman is supposed to know so that she might make a good and successful wife. As you go through life all these things and what I am now telling you will be of great benefit to you. You will be in a position to teach your children if you have any. It is silly to exchange too many glances and smiles with this young man, especially in the presence of people. He will think you are too easy and immoral. When he comes to see you at night you must never run away from him. If you do so this indicates that you are silly and not sufficiently taught and educated to respect the attentions of a suitor. You must never consent to marry your suitor the first time he asks you to marry him, no matter how good looking he may be. Tell him you would like to associate with him for some time yet to come. And if he really thinks anything of you he will not be discouraged, but will continue his visits and come to see you. When he comes at night do not let him stay too long, but ask him please to go. If you let him stay till he is ready to go he will think you are in love with him and will surely think less of you. You must always be sure to take great care to tie the hide under your dress, covering your pudendum, with strong raw hide string. You must remem-

[1] Compare Grinnell, loc. cit., vol. 1, p. 131. Though not exploited by modern ethnologists "roping" was common enough among Indians of the Great Plains; for the Sioux see Beckwith, M. W., Journ. Amer. Folk-Lore, 43, p. 361, footnote 2; for the Assiniboin see Denig, 46th Ann. Rep. Bur. Amer. Ethnol., p. 590; for the Arapaho, cf. Vestal, S., Kit Carson, p. 122; for the Cheyenne and Arapaho see also Dodge, Col. R. I., Our Wild Indians, pp. 195, 196, 203, 212, 213. For the benefit of those who are not specialists I am constrained to say that Colonel Dodge's book can be used only with discrimination. I pass over such absurdities as the statement (p. 204) that an unmarried girl is never sent out to cut and bring wood, etc., for these are easily controlled by general factual knowledge as well as numerous documentary sources of information. Much more subtle than this are various statements regarding sex mores which are scattered throughout the book. The trained ethnologist will see that they are incompatible (see for example, pp. 195, 196, 203, 208, 211, 213 as opposed to pp. 210, 213); the casual reader will not. It is largely owing to the uncritical use of such sources that the main thesis of Briffault's The Mothers cannot be sustained. I lay stress on this because zoologists will pounce upon this work to bolster their own theories regarding human social origins (see now Miller, G. S., jr., The primate basis of human behavior, Quart. Rev. Biol., vol. 6, pp. 379-410).

ber that when a man touches your breasts and vulva he considers that you belong to him.[1] And in the event that he does not care to marry you he will not hide what he has done to you, and you will be considered immoral. And you will not have a chance to marry into a good family. In short, you will not be purchased, which is surely the ambition of all young women.[2] What I mean by marrying into a good family is that the young man's people are not liars, thieves, or lazy, nor have they committed any offensive crime. If you allow the young man to take advantage of you willingly he will make jokes and sing songs with words about you. The people will know and we will be embarrassed and ashamed, especially since you have been brought up and taught in a good way. You must also bear in mind that there will be other young men who will come to see you. They will want to find out if you will succomb easily. If they are serious and approach the subject of marriage, turn them off by saying something nice about the young man who had been seeing you previously. In any case, you must never say anything bad or call any one names, nor remark on their looks or on the poverty of their people. The old saying is, "The birds of the air fly up above but are caught some day."[3] If you say bad things or call one bad names, the one insulted will crawl into the tipi and fondle you while you are asleep;[4] and he will boast of knowing you. It will also be considered that the man is then your husband. Your denial will not help you. You will be placed at the mercy of gossipers.

After I had reached the age of young womanhood, I was not single very much longer. One afternoon I was visiting my girl chum. When I came home that evening there were a number of old men in my father's tipi; I also noticed much fresh meat. I asked my mother

[1] For touching the breasts compare for the Crow, Lowie, R., The Sun Dance of the Crow Indians, Anthrop. Papers Amer. Mus. Nat. Hist., vol. 16, p. 42, 1915; for the Thompson Indians, Teit, J., The Thompson Indians of British Columbia, Mem. Amer. Mus. Nat. Hist., Anthrop., vol. 1, Jesup N. Pac. Exp., vol. 1, pt. 4, pp. 323, 324, 1900; for the Lillooet, Teit, J., The Lillooet Indians, Mem. Amer. Mus. Nat. Hist., Anthrop., vol. 3, Jesup N. Pac. Exp., vol. 2, pt. 5, p. 268, 1906; for the Shuswap, Teit, J., ibid., pt. 7, p. 591, 1909; for the feeling of ownership after touching the vulva, I have abundant confirmatory statements from various Cheyenne informants; see also Beckwith, loc. cit.; cf. also Czaplicka, M. A., Aboriginal Siberia, Oxford, pp. 84, 87, 1914.

[2] Compare also Lowie, R., Primitive society, New York, 1920; Dorsey, J. O., Siouan sociology, 15th Ann. Rep. Bur. Amer. Ethnol., p. 242, 1897, quotes Matthew to the effect that among the Hidatsa the woman is not merely sold to the highest bidder. Among the Fox Indians of today the exchange of goods is the important point; it is not purchase.

[3] As is known, proverbs, charades, the story within the story, the riddle, animal tales of the type of "The Fox and the Crow" are either unknown or very rare in aboriginal America.

[4] A similar trick was done among the Crow Indians; but the guilty man thereby was automatically barred from leadership in the white clay expedition of the Sun Dance. See Lowie, R., Social life of the Crow Indians, Anthrop. Papers Amer. Mus. Nat. Hist., vol. 9, pt. 2, p. 221, 1912; The Sun Dance of the Crow Indians, ibid., p. 42. For the same trick among the Sioux, See Beckwith, loc. cit.

what it was all about, and what those old men were here for. She said, "My daughter, these men are here to deliver a message, asking the consent of your father that you marry a male of their family.' And I want to tell you that your father has consented. However, he will speak to you later." My father said to me, "My daughter, these men have come here to ask my consent to your marriage. Five horses and other things will be sent over in the morning. I have consented. Now I myself want to hear what you think." I made no reply. I was frightened. But at any rate the horses were brought over the next morning. My male relatives were called to select their horses, but before doing that they called me in and asked me what I thought. My paternal uncle started to talk to me saying how well my parents had brought me up, and stated that marriage by purchase was considered one of the greatest and happiest events in one's life.[2] He said, "I know that this is your father's desire. As you can see, he is getting on in years. His eyesight is not very good. This young man will look after the necessary work for your father. However, we do not wish to do anything against your will. Now, let us hear from you." I then said to them, "Since my father has consented to the offer of marriage by purchase, I also agree to the proposed marriage. I love my father, and whatever he deems best for me, that I will do. I cannot refuse my father's wishes for those reasons."[3] They were all glad to hear me, showing it by their sincere approval.

They then proceeded to select their own horses, one at a time. They were all good saddle horses. They in turn gave their own horses. My people saddled one of the horses on which I rode over to my future husband's people, leading the four other horses. My future husband's women folk met me near their camps and I dismounted. They carried me on the blanket the rest of the way, and let me down at the entrance of my future husband's tipi. I walked in and sat beside him. This young man was no sweetheart of mine; he was a stranger to me: he never had come to see me when I was still single. I wondered if I would learn to love him in the future. After some little time the women brought in many shawls, dresses, rings, bracelets, leggings, and moccasins. They then had me change clothes. They braided my hair[4] and painted my face with red dots on my cheeks. When I was completely arrayed in my marriage clothes I was told

[1] On Cheyenne marriage see Grinnell, loc. cit., vol. 1, pp. 137 et seq.

[2] See footnote 2, on page 5.

[3] If Grinnell is right, this reply is not institutional but personal. From my own field-work among the Plains Cree, I can vouch that there at least the girl has the final say.

[4] For the braiding of the hair of Cheyenne females see Grinnell, loc. cit., vol. 1, pp. 59, 60.

to return to my people. My husband's women folk carried the balance of my clothing to my tipi. In the meantime my mother and aunt had prepared a large feast. Towards evening my own tipi was erected. The cryer called in a loud voice inviting all my husband's relatives, naming my husband as the host. My husband came over with his male relatives. While there they told jokes, and some related their war exploits; still others narrated funny things that had happened to them in the earlier days.

After I was married I thought I would have more freedom in going around with my girl friends, but my mother watched me more closely and kept me near my husband, day and night. This was done to prevent any gossip from my husband's people.

A year or so before I married we played games. In the fall of the year we played "kick ball." [1] This is played by kicking and counting the number of times the ball is kicked with one foot with the ball not touching the ground. Some girls could keep the ball in the air with a tally of 50 or 60. We had tally sticks to keep count, 150 of them. The side that won took the ball. The losers ran away from the winners who chased the losers all about the camp, pounding them on the back with the ball. This created merriment and excitement. Even those who did not participate in the "kick ball" game were tagged and became "it." A person tagged before could not become "it." The losers were supposed to give food to the winners, and so the game ended.

There was another game played by us young women on the frozen lake or river. We had dart sticks 10 or 12 feet long, smooth and straight. In one end of the dart sticks was the tip of a buffalo horn, about 4 inches long. The dart stick was thrown with great force on the ice and it slid a great distance.[2] This was a sort of gambling game. We bet our ear rings, finger rings, bracelets, hair-braid ties, and other things.

In the spring of the year we played shinny, using clubs to drive the ball. There were 20 to 40 players on each side.[3]

With the approach of summer our attention was directed to horseback riding. Even after I was married my husband and I would travel on horseback. It was a long time before we had a wagon.

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[1] See Culin, loc. cit., p. 706; Grinnell, loc. cit., vol. 1, pp. 330 et seq.; Petter, loc. cit., p. 831.

[2] See Culin, loc. cit., pp. 399, 400, 401; Grinnell, loc. cit., vol. 1, pp. 334, 335; Petter, loc. cit., p. 830.

[3] See Culin, loc. cit., p. 620; Petter, loc. cit., p. 828.

My parents continued to care for us.[1] My mother did all the cooking,[2] but my husband's meals were always taken to our own tipi. This was for me to do. My mother and my husband were not allowed in the same tipi at the same time.[3] My mother took especial care that my husband received the best portion of food. My husband's duty was to look after the horses and do all the work that was required of a man.

We had our first child after we had been married a year. It was at this time that I began really to love my husband. He always treated me with respect and kindness. We had eight children before he died. The first decorated tipi I made was after I had had my fourth child.[4] Of course when I was a girl my mother permitted me to look on when

[1] Matrilocal residence is attested for the Cheyenne by both Grinnell (loc. cit., vol. 1, p. 91) and Mooney (with the qualification "not always"; see his The Cheyenne Indians, Mem. Amer. Anthrop. Assoc., vol. 1, pt. 6, pp. 410, 411, 1907). It is confirmed by my own field-work. Matrilocal residence is a very different thing from exogamy with female descent. This last is claimed for the Cheyenne by Grinnell: see his Social Organization of the Cheyennes, Proc. Internat. Cong. Americanists for 1902, pp. 135-146, New York, 1905; The Cheyenne Indians, vol. 1, pp. 90 et seq., New Haven, 1923; per contra see Clark, W. P., The Indian sign language, p. 229, Philadelphia, 1885 [Mooney's reference to p. 235 also, is due to some error]; Mooney, J., The Ghost Dance religion, 14th Ann. Rep. Bur. Amer. Ethnol., p. 956, 1896; Mooney, J., Kiowa calendar, 17th Ann. Rep. Bur. Amer. Ethnol., p. 227, 1898; Mooney, J., The Cheyenne Indians, Mem. Amer. Anthrop. Assoc., vol. 1, pt. 6, pp. 408-410, 1907. I do not think it can be said that Grinnell has successfully contested Mooney's strictures. My own field-work among the Cheyenne (beginning in 1911) confirms Mooney's position by statements of informants and genealogies. I wonder if Grinnell's informants may not have had Crow blood and thus given a wrong impression, for the Crow are organized in exogamic groups with female descent. In justice to Grinnell it should be noted that he expressly states that "evidence of a clan system is not conclusive."

[2] For other courtesies shown by a Cheyenne mother-in-law to her son-in-law, see Grinnell, The Cheyenne Indians, vol. 1, pp. 146, 147, New Haven, 1923.

[3] Though this particular avoidance is only implied by Grinnell, loc. cit. vol. 1, p. 147, there is no doubt that it was institutional among the Cheyenne; the same thing occurs among the Assiniboin, Blackfoot, Gros Ventre, and probably elsewhere: see E. T. Denig, Indian Tribes of the Upper Missouri, 46th Ann.. Rep. Bur. Amer. Ethnol., p. 511, 1930; Kroeber, A., Ethnology of the Gros Ventre, Anthrop. Papers Amer. Mus. Nat. Hist., vol. 1, pt. 4, p. 180, 1908; Wissler, C., The social life of the Blackfoot Indians, Anthrop. Papers Amer. Mus. Nat. Hist., vol. 7, pt. 1, pp. 12, 13, 1911.

[4] Four is the "holy" number among the Cheyenne. See Dorsey, G. A., The Cheyenne, I, Ceremonial organization, Field Columbian Mus. Publ. 99, Anthrop. Ser., vol. 9, no. 1, pp. 1, 3, 5, 7, 10, 11, 12, 16, 19, 20, 23, 28, 32, 33, 1905; II, The Sun Dance, Field Columbian Mus. Publ. 103, Anthrop. Ser., vol. 9, no. 2, pp. 60, 63, 91, 96, 99, 100, 144, 159, etc., 1905; Grinnell, loc. cit., vol. 2, pp. 197, 205, 214, 227, 228, 229, 236, 237, 245, 251, 257, 288, 289, 291, 292, 297, 321, etc.; Mooney,

she made decorated tipis. There is a rather long ceremony in connection with the making of tipis. I became a member of the "Tipi Decorators," which is composed of women only.[1] I was very carefully instructed never to disclose the ceremony in the presence of males. So I shall be obliged to discontinue the subject.

My husband's health became broken. We summoned many Indian doctors, and gave away much personal wearing apparel, and also some ponies. One day when we were alone he pledged a Sacrifice Offering. This ceremony is a sacred ritual which is regarded as a prayer to the spirits for strength and health. When he made the pledge this included me, for the rule requires that a wife must be included. But sad to say, he passed away before we could carry out the pledge.

Four of my younger children also died later. It was a good thing for me that my father and mother were still living. I did not really have a hard time to support my children.

I surely loved my husband. His death made me very lonely, and it was a terrible event in my life. Apparently I missed him more than I did my children who died afterward. My hair was cut off just below my ears.[2] This was done by an old woman who had obtained the authority by participating in one or more sacred ritualistic ceremonies previously. Before cutting off my braids she first raised both her hands towards the sky, touched the earth with the palms of her hands, laid her hands on my head, and made a downward motion, repeating the motion four times. Thus my braids were cut off in accordance with the belief that the spirits would be pleased and extend blessings and sympathy to the bereaved. The old woman who cut my hair was given a blanket and a dress.

The death of my husband marked the passing of our tipi, including all the contents. If people do not come and carry away something, the whole tipi is destroyed by fire.[3]

J., The Cheyenne Indians, Mem. Amer. Anthrop. Assoc., vol. 1, pt. 6, p. 411, 1907. It is extremely common among North American Indians, but Mooney's generalization is too sweeping; see for example, Lowie, R., Primitive religion, p. 284, New York, 1924.

This note applies to all the references to the number four in the following pages.

[1] See Grinnell, loc. cit., vol. 1, pp. 159 et seq., for female societies among the Cheyenne; also Petter, loc. cit., article "bead," pp. 97, 98.

[2] Compare Grinnell, loc. cit., vol. 2, p. 161. The same thing occurs elsewhere, *e. g.*, among the Arapāho, Gros Ventre, and Blackfoot: see Kroeber, A., The Arapaho, Bull. Amer. Mus. Nat. Hist., vol. 18, pt. 1, p. 16, 1902; Kroeber A., Ethnology of the Gros Ventre, Anthrop. Papers Amer. Mus. Nat. Hist., vol. 1, pt. 4, p. 181, 1908; Wissler, C., The social life of the Blackfoot Indians, Anthrop. Papers Amer. Mus. Nat. Hist., vol. 7, pt. 1, p. 31, 1912.

[3] See also Grinnell, loc. cit., vol. 2, p. 162.

After two years I heard that a man had pledged a Sacrifice Offering.[1] My father and mother immediately advised me to go and see this man in order to be permitted to fulfill my deceased husband's pledge. My father said the pledge could not be set aside and neglected any longer, in spite of what had happened in the past.[2] So I went to see this man and his wife. They readily agreed to my request. They told me to be ready soon thereafter. They said they had everything that was needed in connection with the ceremony and that I need not worry about these things. They also said he had taken the sacred pipe to the priest to teach and lead them. This pleased me greatly as I had nothing to do now, and only waited to be notified when all was ready. The day before the ceremony proper green timbers were brought from the forest in order to have them in readiness for the following day. The day the timber is brought in the tipi is erected, that is, in the evening.

The ritualistic ceremony itself begins early the next day. The pledgers are required to dress in their best clothing. The clothing thus worn becomes the property of the painters. The first thing the priest does is to prepare the Sacrifice Offering cloth. Though other things can be used, such as black, white, red solid-colored or striped cloth—and gray eagle also—we used a striped cloth which the priest tied to a long stick. This is, of course, inside of the tipi. After this the priest smokes the medicine pipe and points the mouthpiece of the pipe to the four directions of the earth and towards the skies. The pipe is then passed to the left. The first person on the left of the priest smokes it, and so on, down to the doorway. The pipe is then passed backward without being smoked and is passed to the right of the priest until it reaches the last person near the doorway. This person smokes it, then the next person on his left, and so on until the pipe again reaches the priest. He then empties the bowl of the pipe. The pipe is then put away. The priest instructs the pledgers how to raise and point the stick to the proper directions when they go out. They then go outside. The person in the lead takes the stick and cloth. The priest begins to pray, and then sings medicine songs. At the end of each song he tells those outside to point the stick southeast, then southwest, then northwest, then northeast, and then straight

[1] Though this particular ceremony apparently is absent from published works on the Cheyenne, it is abundantly clear that the elements which compose it are simply old Cheyenne material recombined in slightly varying ways. The annotations will bring this out more clearly. Years ago I demonstrated the same thing for Fox gens festivals.

[2] The nonfulfillment of a pledge was fraught with supernatural disaster; compare Grinnell, loc. cit., vol. 2, p. 195.

towards the sky. Anyone may then take the cloth and touch one's body all over with it, thereby receiving a blessing from the spirits.

They then reenter the tipi. The ground is then broken by making dents in the earth four times, in the same manner as the pointing previously. The ground is made very smooth, and a hole is made for a fireplace in the center. Clean white sand is then laid on this clearing, representing the sky.[1] The coals of fire are scattered here and there, representing stars. There are four holy places on the sand, the home of the spirits; and the holes are made in the same sequence of directions as given above. The path from the entrance into the tipi is marked with powdered coals towards the fireplace. A full moon [2] is between the fireplace and the entrance. Beyond the fireplace is the crescent moon.[3] These moons are made of black powdered coals. There are four buffalo chips [4] placed in front of the priest. The medicine bags are placed on top of the buffalo chips before they are untied and opened. Before they are opened the priest spits medicine on one's hands four times, and passing motions are made, first using the right hand by making a drawing motion on the right leg, then the left hand on the right arm, next the right hand on the left arm, then the left hand on the right leg; and both hands backwards over the head.[5] This is required for old people. Young women are required to make a downward motion in front of their bodies, indicating an easy child-birth.

The pledgers are stripped of their clothing. The painters paint their bodies red; but in the case of women their arms and legs are painted, but not their bodies, and their faces are painted red with black circles all over; others have the paint represent the ground, namely, four black specks on the face and middle of the nose. When the painting is done, coals of fire are taken from the fireplace. Pinches of medicine are placed on fire which is in front of each person. Motion is made with both hands towards the smoke, and inhalation takes place. During the performance the priest sings medicine songs, one song for each performance. When all is done the pipe is pointed [6] to the four directions without being lit, and after it

[1] For the ceremonial use of sand compare Dorsey, G. A., loc. cit., vol. 2, p. 65; Grinnell, loc. cit., vol. 2, p. 261.

[2] For the ceremonial use of a full moon compare Grinnell, loc. cit., vol. 1, p. 196.

[3] For the ceremonial use of the crescent moon compare Grinnell, loc. cit., vol. 1, p. 193; vol. 2, pp. 24, 270.

[4] For the ceremonial use of buffalo chips compare Grinnell, loc. cit., vol. 1, pp. 87, 121; vol. 2, pp. 18, 32, 37, 57, 245; etc.

[5] The ceremonial motions described by Grinnell, loc. cit., vol. 1, p. 160, are nearly the same.

[6] For pointing the pipe, compare Grinnell, loc. cit., vol. 2, p. 270.

is lit it is again pointed to the four directions. After the pipe is emptied the priest calls the pledger to come before him. The priest holds the pipe in his right hand; he spits on the outstretched right hand. The pledger then grasps the stem of the pipe held by the priest with the bowl towards the ground. The pledger clasps the hand of the priest, and both hold the stem of the pipe. The pledger gently pulls the pipe towards himself four times. The fourth time the priest lets go. The pledger takes the pipe, first placing it on his right breast, then on the left, then right, then left; he hands the pipe back to the priest. He makes drawing motions over his limbs as before, and then proceeds to touch the holy ground exactly as with the drawing motions. After this, all may touch the holy ground. This terminates the ceremony in the tipi.

All this time the Sacrifice Offering cloth and the stick leaned against the breast of the tipi, and green timbers leaned against the back of the tipi. The women now take charge of the timbers, and proceed to build a sweat lodge.[1] The first two timbers are planted on the east and the two on the west; these sets are about 2 feet apart. Then the remaining timbers, about 13, are put in the ground, forming a circle about 8 feet in circumference. This will accommodate about 15 persons. A round hole is made in the center of the sweat lodge. This is a place for hot stones; it is about 2 feet in circumference and 1 foot deep. The dirt taken from the excavation is placed about 20 feet towards the east of the entrance, and is made into a small mound.[2] This mound and the sweat lodge are connected by a trail. Then a young cottonwood tree[3] is placed in the ground in an upright position near, but east of, the mound. A buffalo skull[4] is then placed against the mound; it is on the west slope[5] and faces the sweat lodge. The skull is painted with black and red paint: the horns are blackened, and the region around the nose is painted red; a black streak runs from the back of the head to the tip of the nose.[6]

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[1] See especially Petter, loc. cit., article "sweat lodge"; for the use of sweat lodges in religious ceremonies see also Lowie, Primitive religion, p. 195, New York, 1924.

[2] Compare Grinnell, loc cit., vol. 2, p. 103.

[3] For the ceremonial use of cottonwood trees, see Grinnell, loc. cit., vol. 1, p. 95; vol. 2, pp. 229-232, 259, 287.

[4] For the use of a buffalo skull in combination with a sweat lodge, see Grinnell, loc. cit., vol. 2, p. 103.

[5] For the localization of the buffalo skull on the west slope, compare Grinnell, loc. cit., vol. 2, p. 294.

[6] The buffalo skull is painted nearly as in the Sun Dance; compare Dorsey, G. A., loc. cit., vol. 2, pp. 96, 97: in part compare Grinnell, loc. cit., vol. 2, p. 33.

The wife of the pledger carries the skull from the tipi to the mound.[1] She carries it in a stooping position, very carefully and slowly. Five stones are then selected. Two are painted black, a third is not painted, the last two are also painted black. After this they are not handled with the hands, but are put in place with forked sticks between the mound and the sweat lodge, a little to the south of the trail. Motions are made with the hands four times towards the stones before the stones are forked. These stones are placed in the same manner as the holy places within the tipi but are closer together, the fifth stone being in the center. The dried wood and other stones are then placed without any ceremony. However, before fire is added to the heap, the heap is touched four times with a fork in the same manner as the stones. In the meanwhile the women cover the hut with heavy canvas. Blankets, fine clothing, and other things are placed on top of the canvas. These become the property of the priest and his helpers (who are the painters). The property is divided according to what the priest and his helpers gave when they were pledgers. If one or more horses are given away, the ceremony is conducted in the daytime. If not, it is conducted at night.

The priest and pledger enter the sweat lodge with the paint still on them and go over the ceremony as in the tipi, except that they remove the paints put on by the painters, using sage[2]; water is drunk, and their bodies are washed. When the hot stones are brought in, two are brought in first, then one, then two. They then are placed in the same order as they were before they were heated. The remaining stones are then brought in. The sweat bath now begins. The priest utters a prayer and sings songs. The doorflap is raised; also the rear is raised, thus airing the bather. This is done four times, and each period lasts about 20 minutes. When this is over we all go back into the tipi, when our relatives bring in all kinds of food for us to eat. Before we eat, bits of food are placed on the holy ground and drawing motions on the body are performed. We then proceed to eat. The sacred medicine bag is in a crescent shape[3]; it is made out of raw hide. The inner bag is an entire prairie dog skin which contains the sacred herbs.

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[1] For the pledger's wife carrying the buffalo skull, see Dorsey, G. A., loc. cit., vol. 2, pp. 107, 108; Grinnell, loc. cit., vol. 2, p. 291.

[2] The use of sage for ceremonial purposes is common enough. See Dorsey, G. A., loc. cit., vol. 2, p. 159; Grinnell, loc. cit., vol. 2, p. 423.

[3] See footnote 3, on page 11.

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CLASSIFICATION

The Caddoan linguistic stock, named after the language of the Caddo, is composed of four major languages, Pawnee, Wichita, Kitsai,[2] and Caddo. Of these, the Kitsai had never developed dialectic differentiation; the Wichita and Caddo probably each included several dialects, but as at present spoken are known only in one form; and the Pawnee today occurs in three dialects. On the basis of present knowledge, the broad relationships of the four languages can be indicated as follows: Pawnee, Wichita, and Kitsai are, in relation to each other, about equally divergent, save that Kitsai in phonetic structure and some forms is probably closer to Pawnee than Wichita is to Pawnee. All three, however, are mutually unintelligible. Caddo is the most divergent of the four languages. The general interrelationships of these languages and their dialects can be summarized by the following table:[3]

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[1] Based on field research for the Committee on American Indian Languages.

[2] The authors have preferred this spelling of Kichai. Kitsai approximates more closely the phonetic character of the native name.

[3] In the transcription of native names and words of this treatment, the authors have followed the recommendations embodied in Phonetic Transcription of Indian Languages, Smithsonian Misc. Coll., vol. 66, no. 6, September, 1916. Briefly summarized, the characteristics represented are as follows:

Consonants:

b, m, n, h, and y have their usual values.

p, t, and k (except in Caddo) are intermediates, neither quite sonant nor quite surd. Pawnee final t is nasalized, indicated by superior n (t^n). Caddo t is surd d sonant; Caddo k is, however, intermediate.

s is throughout surd, somewhat more sibilant than English s.

c is the usual sound of sh in English show.

x closely approximates the ch of German ich.

r in Pawnee and Arikara is a single trilled r made with the tip of the tongue on the alveolar ridge (see also Boas, Handbook of American Indian Languages, Bull. 40, Bur. Amer. Ethnol., pt. 1, p. 17, 1911); in Kitsai and Wichita where a distinct n occurs, the r more nearly approximates the English r, but it is never made as far back in the mouth or trilled as strongly. Caddo r is more strongly trilled.

The affricative ts is intermediate where t is intermediate. In Caddo it is surd.

I. Pawnee, Kitsai, and Wichita.
  A. Pawnee: a) South Band Pawnee (or Pawnee proper); spoken by:
      pi·ta̯hawíra·t^{a}
      tsa̯wî·'^{ι}
      kιtka̯haxki^{x}
    b) Skiri[1] Pawnee
    c) Arikara
  B. Kitsai: ti̯kítsε·s band of the Wichita.
  C. Wichita: a) Wichita proper, spoken by:
      toka'nε
      ιsí·s
      tiwá·
      ιtá·
      kι̯rikι̯rí·s
      αkwi·ts
    b) Probably dialectically divergent:
      tawaka̯rúw'
      wéku'
II. Caddo: a) Caddo proper; spoken by:
      nada'rko
      naci̯dóc
      ya't'αs
      nak'oho̯do'tsi
      ha'i·c
      kaya̯ma͡íci
      kado'a̯dátc'^{u}
    b) Hainai; spoken by:
      ha͡ina͡i
      nabada͡ítcu
    ?c) ? Adai

[1] Skiri is used herein for Skidi. The d of earlier records is the Pawnee r; see the phonetic key above.

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tc has its usual affricative character in Caddo, while in Arikara it is more intermediate.

w is slightly more rounded than in English.

Vowels:

With a few exceptions, the symbols for vowels indicate the usual continental values as follows: *a* as in father; α (Greek alpha) as u in but; *e* as a in fate; ε (Greek epsilon) as e in met; *i* as ee in feet; ι (Greek iota) as i in hit; *o* as o in go; *u* as oo in hoot. Exceptional is ε in Pawnee, where in making the sound the lips are very

SUBDIVISIONS

PAWNEE

Of the three Pawnee dialects, that known as South Band Pawnee or Pawnee proper preserves the oldest forms of Pawnee. The dialect of the Skiri differs from the South Band Pawnee primarily in phonetics. Speeds, lengths, and tones differ between these dialects; but most important is the fact that the phonetic changes which have occurred have resulted in Skiri in the loss of a number of vowel and consonant distinctions that are found in South Band Pawnee. As a result, what was already a meager phonetic system in Pawnee proper is still further reduced in Skiri.[1] While it may well be true that historically—as tradition claims—the Arikara dialect diverged from a root which was once common to Arikara and Skiri, nevertheless on the basis of a comparison of the three Pawnee dialects as spoken today, the Arikara divergences should be treated in relation to the Pawnee proper or South Band dialect, rather than in relation to the speech of the Skiri. The phonetic divergence of Arikara can be characterized in two ways: first, there are many shifts of vowels and consonants, numbering many more than those which differentiate Pawnee proper and Skiri; and second, in Arikara enunciation whole syllables are lost to the ear through elision and whispering of the vowels. Today, South Band and Skiri dialects are almost fully mutually intelligible; older natives understand the speech of the other group but reply in their own, while among the young people there is a tendency to develop a mixed dialect which overrides the differentiation of the two. Skiri and Arikara generally insist that they can understand one another, and some do; but

[1] Material on which these statements and those referring to the Arikara are based, as well as the details of the phonetic shifts, will be given in an analytic study of comparative text material.

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wide, the aperture between them forming a very narrow slit; and *e* in Pawnee which does not have the usual diphthongal quality.

ω̱ (Greek omega) of Wichita is the aw of English law.

a͡i of Caddo is the diphthong of English height.

Diacritical marks:

The glottal catch (') and the aspiration (ʻ) are used in the usual way. Stress accent is indicated by (′) after the syllable (a′). Vowel length is indicated by (˙) after the vowel (a˙); vowel shortness by (◡) under the vowel (a̯). Pitch accents are (á) for high tone, (à) for middle high. Tone combinations occurring in Pawnee are: (â˙) high to middle high, (ã˙) normal to middle high, (ā˙) middle high to normal, (ǎ˙) middle high to high.

Whispered or slightly articulated sounds are indicated as superior symbols (tᶜ).

for the most part, this seems due more to their control of a smattering of the other dialect than to any inherent possibilities of intelligibility, which are in fact slight because of the character of the phonetic changes which have taken place. Actually an Arikara was not able to understand a Skiri text, but was at once able to grasp the same text in South Band Pawnee and translate or transpose it into Arikara. There is still current among the Pawnee a tradition that the Ka̯wárā·kıs group of the Pi·ta̯hawíra·t^{a} spoke like the Arikara. It is impossible at the present day to check this tradition, and it seems unlikely that it was true. The few suggestions of linguistic difference between Ka̯wárā·kıs speech and Pawnee proper which can be obtained, point rather to earlier dialectic differences in the speech of the South Bands. Traditions support this view strongly, all South Band Pawnees of the older generations insisting that when the bands lived apart there were differences in their speech, which disappeared after they came to live together. Texts taken from the oldest living representatives of each band failed to show any vestige of such differences remaining today.

The Pawnees have no name for themselves which includes as a unity the four bands of Tskiri, Tsa̯wî·'^{ι}, Pi·ta̯hawíra·t^{a}, and Kítka̯haxki^{x}. These bands were known to themselves and to each other by their band names. The absence of a general tribal name reinforces other evidence for the fact that the four bands never formed an integrated tribal unity; in fact, they were in former times independent tribal groups. They often banded together for the buffalo hunt and other collective enterprises. But the Skiri, for example, were no more likely to join the three South Bands for a buffalo hunt in the early nineteenth century, than they were to join the Omahas and Poncas. This fact of the essential political independence of each of the bands is too often overlooked, in part because the United States Government has for long dealt with all the Pawnees as one group.

The words "chahiksichahiks" (tsa̯hiksı̯tsahiks), often quoted as the name of the Pawnees for themselves[1], has quite a different use. It is not a word for the Pawnees as distinguished from other Indians. tsa̯hiks—is "person", "human being", the generic word, as distinct from words for "man", "woman". In the combination the connective—ı—has prepositional value rendered somewhat by the translation "men of men" or "people of people". This combination "men of men" implies "civilization" on the part of the persons

[1] Fletcher, A. C., Handbook of American Indians, Bull. 30, Bur. Amer. Ethnol. (cited hereafter as Handbook), pt. 2, p. 214, 1910.

referred to. tsąhiksti'ʻ, "he's a man", "he's really a human being", implies the idea that a man's ways are civilized, well-mannered, gentle. A wild, ill-mannered, mean man would be called tsąhikskaki'ʻ, "he's not a human being". Thus tsąhiksįtşahiks is applied by the Pawnees not alone to themselves but also to other Indian groups of their acquaintance whom they considered civilized, such as the Poncas and Omahas. In a general way it was also used for Indians as opposed to white men.[1]

The name Pawnee is one which was first applied to the Pawnees by white men. It seems unlikely for linguistic reasons that its use came from pąrí·ku', "horns", as suggested in the Handbook.[2] Our informants claimed that it derived from pąrí·sᵘ', "hunter" (Skiri dialect). They said that the first Pawnees to meet white men were on the hunt, and that when the white men asked, "Who are you?" an Indian answered, "pąrí·sᵘ'", "a hunter". In the light of this possible derivation, it is interesting to note that the spelling of Pawnee on the early maps is "panis", and also that in more recent years several recorders have written Pawnee "r's" as "n's" because of the peculiar phonetic character of the Pawnee "r". Clearly from "les panis" a derived singular would be pani or Pawnee.[3]

The Skiri derive their name from the word for the wolf. In present day usage this is tskįrɪxkⁱˣ (adding the diminutive), but it may well have been the shorter form earlier (tskiri). The Skiri were known to themselves and to other tribes as "wolves".[4] Their war whoop was the cry of the wolf, and for deception on the warpath and in scouting they dressed as wolves, and signalled each other vocally with wolf cries.[5] In war dances where combat is dramatized the warriors act like wolves. A mythological background for this

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[1] This usage is also quoted from Hayden, Handbook, pt. 2, p. 216.

[2] Handbook, pt. 2, p. 213.

[3] Some years ago James R. Murie suggested to F. W. Hodge *paresᵘ* as the origin of Pawnee, and told the same story about it. See Amer. Anthrop., n. s., vol. 17, pp. 215–216, 1915. Apparently the story is a general Pawnee tradition.

[4] Dunbar, J., in Mag. Amer. Hist., vol. 4, p. 259, 1880, offers as explanation of the name Skiri the association of this group of Pawnees with the Loup (Wolf) River, which in turn was so called because of the abundance of wolves along the stream. Pawnees of today still recall that wolves were abundant along the Loup River in early days. It seems reasonable to believe that such a wolf-teeming habitat had an important influence on Skiri Pawnee cultural forms, and thus was indirectly responsible for the name.

[5] Grinnell, G. B., Pawnee hero stories and folk tales (cited hereafter as Grinnell), pp. 245–248, 1890, describes these methods of deception in some detail; the statements made herein are based on information from present-day informants.

conception is furnished by an incident in the story of Lightning's visit to the earth carrying all people in a sack. The Wolf-Star, being jealous of the Evening-Star who has sent Lightning to the earth, sends a wolf to steal Lightning's pack. When the people come out and observe the wolf's strange behavior, they kill him, thus introducing death into the world. Lightning tells them to skin the wolf, and to keep its hide on their sacred bundle. He tells them also that wolves will multiply, and that they shall be known as Tskiri.[1]

While there was no name for the four Pawnee bands together, an old informant stated that in Nebraska the Skiri used to speak of the other three bands together as tu̯hā·wιt^{n} (in South Band dialect the word is tuxrā·wιt^{n}) which means "village-east". This evidently refers to the position of these bands in relation to the Skiri. The orientation of the Pawnee bands in Nebraska according to present informants was schematically as follows:[2]

N

W tskiri kιtka̯haxki^{x} tsa̯wî·'ι pi·ta̯hawíra·t^{a} E

S

It is a matter of interest that contrary to the theoretical statements that the Pawnees always maintained the same orientations of the bands, the band locations in Oklahoma are about as follows:

N

tskiri

W tsa̯wî·'ι E

kιtka̯haxki^{x}

pi·ta̯hawíra·t^{a}

S

The three bands which spoke South Band dialect or Pawnee proper did not, however, have any name for themselves as a unit group. Nevertheless restrictions upon intermarriage between bands

[1] Dorsey, G. A., Traditions of the Skidi Pawnee, Mem. Amer. Folklore Soc.' vol. 8, pp. 17–18, 1904.

[2] Dunbar, op. cit., pp. 257–258, discusses the location of the bands as they were oriented to each other in 1834. While his statements are ambiguous, their most likely interpretation would make the band orientation agree with the statements of our informants. Dunbar also gives tu'-ra-wit-u, eastern villages, as the name applied by the Skiri to the other bands.

Fletcher, A. C., Handbook, pt. 2, p. 214, gives the relative positions exactly as we have recorded them. Grinnell, p. 218, also gives this order. Inasmuch as our records were secured independently from Pawnees who had moved to Oklahoma from Nebraska, and who knew the facts only from memory and tradition, they are important confirmation of the earlier statements.

broke down earlier among the three South Bands, and marriages were tolerated between tsa̯wî'ʻ and pi'ta̯hawíra'tᵃ at a time when they were still frowned upon between any one of the three bands and the tskiri, indicating a closer affiliation of the peoples of the South Bands.

The name pi'ta̯hawíra'tᵃ can be analyzed as meaning "man who goes east": pi'ta—"man", hawíra'tᵃ—"goes east." The latter is a combination derived from ă'wιtⁿ—"east" and íră'tᵃ—"one who goes."[1]

According to the writings of James R. Murie,[2] the pi'ta̯hawíra'tᵃ were formed of two villages: the pi'ta̯hawíra'tᵃ proper and the kawa̯ră'kιs. Informants today state that while these two groups did not live apart, but formed one village, they did speak different dialects, as above noted, and also had independent bundles and ritual and ceremonial performances. The name kawa̯ră'kιs simply refers to the fact that these were the people who had or owned the kawa̯rá'ᵃ bundle, which seems to have been one of the most ancient bundles of the Pawnees, certainly the oldest of the pi'ta̯hawíra'tᵃ bundles. An indication of the conceived relationship of the two groups is given by the kinship terms which they used for each other. The kawa̯ră'kιs called the pi'ta̯hawíra'tᵃ tsku̯'rus, "in-law", while the pi'ta̯hawíra'tᵃ replied ri̯kura̯kátsku̯'rusu', "they are in-laws to us".

kιtka̯haxkiˣ means literally "little mud lodge". "On a hill", the meaning given by Grinnell[3], has no linguistic basis.

Murie speaks of four divisions of the kιtka̯haxkiˣ:[4] "the kιtka̯haxkiˣ proper, the little kιtka̯haxkiˣ, the Black Heads, and the kari̯ki'su or 'one who stands in the circle to recite the creation ritual' ". A number of informants agree that there were not four divisions of the kιtka̯haxkiˣ band. Informants state that there were two divisions, the kιtka̯haxkiˣ proper, called kιtka̯haxkisúra̯riksι̯sᵘ (ra̯ríksι̯sᵘ, "real"), and the little kιtka̯haxkiˣ, called

[1] Grinnell, p. 216, gives " 'down the stream', or east" as the meaning of this name. There are two usages for east in Pawnee, of which one means "outsideᵃ through the entrance", referring to the fact that the doorway of the Pawnee earth lodge is oriented toward the Morning Star and the rising sun, hence eastward; while the second usage, ă'wιt as above, is related to the stem for floating, hence has a downstream connotation. As all rivers flowed eastward or southeastward from the Pawnee villages in Nebraska, the word has come to be used for east.

[2] Murie, J. R., Ceremonies of the Pawnee. To be published by the Bureau of American Ethnology.

[3] Op. cit., p. 216.

[4] Op. cit.; Grinnell, p. 241, speaks of three.

kıtkahaxkiripatski (kiripatski, "small"), and that the latter group split off from the main band not more than three generations ago under a self-made chief, Curly-Chief, téktesaxkarıxku. The camp of the kítkahaxkiripatski was set up southeast of the main village. The Black Heads (pákskā·tit^{n}) was the name of a society; and the kariki·su was the woman's dance or ceremony before the planting of the corn. Between the kítkahaxki^{x} proper and the little kítkahaxki^{x} old informants claim there was a slight dialectic difference of speech; but they lived together in one village and as far back as memory and tradition go, their bundles and ceremonies were merged or the same.

The tsawî·'ι name, according to many Pawnee informants, has the reference "beggars."[1] This could not be established as a linguistic meaning; the closest similarity of the word seems to affiliate it with the stem for "doctoring". Nevertheless, we do not doubt that "beggars" had a relevance which has been lost. People of the other bands claim that the tsawî·'ι always came asking for meat, hence the name. Wissler, in a footnote to Murie,[2] states: "They are now known as tsawî·'ι or Chaui, a band sprung from tsákıtā·ru—ítsat, coon; wi·'ι part of band". This derivation, on close linguistic analysis, does not seem likely; ítsat and ákıtā·ru would combine into tsákıtā·ru in South Band dialect, but ítsat and wi·'ι would combine into tsaxwî·'ι not tsawî·'ι.

The *Arikara* are called arikarā·ru', "horns" or "elk", by the Pawnees, and they call the Pawnees *awáhu.* As the term Arikara is a good Pawnee and Caddoan word, the linguistic derivation of which is clear, it seems unlikely that, as has been contended, the name is not used by the Arikara for themselves.[3] The word means "elk".[4]

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[1] Grinnell, p. 216, gives "in the middle" as the meaning of tsawi·'ι. He probably derives this from a confusion of the name with the word tawe which means "among".

[2] Op. cit.

[3] Gilmore, M. R., The Arikara Book of Genesis, Pap. Michigan Acad. Sci., Arts, and Lett., vol. 12, p. 95, 1929.

[4] The Handbook, under the synonymy of Arikara, lists: "starrahe" from Bradbury's Travels in the Interior of America, and "star-rah-he" from Lewis and Clarke, the latter given by the explorers as the people's own name. Phonetically this is a good Caddoan (Pawnee or Arikara) word (tstarahi), and its suggestive correspondence to the "harahey" "arahey" of Coronado's expedition makes this a plausible alternative derivation of the Coronado name to awahi, the Wichita name for the Pawnees (see below). In the case of awahi, the possibility is that Wichitas spoke of Pawnees to the Spaniards, in that of "star-rah-he" that Turk or some other Pawnee told them about the Arikara.

The word given by Gilmore[1] as the Arikara name for themselves, "sanish" is saxnιc, paralleling the South Band word tsaxriks, meaning "person"; and "san-sanish" is clearly the Arikara analogue of the Pawnee tsaxriksι̯tsaxriks (tsa̯hiksι̯tsahiks) discussed above.

Awahu, the name used by the Arikaras for the Pawnees means "left behind"; it also occurs as the name of one of the Arikara villages.[2] Traditionally it is said to reflect the movements of the peoples, the fact that the Arikaras moved on to the north in the Pawnee migrations and left the Pawnees behind.

While the Arikara spoke of the Pawnees as *awahu*, they also knew the bands by their individual names. These they rendered as follows: stci·ri (tskiri);[3] wi·t^{a}hawíra·^{a}t (pi·ta̯hawíra·t^{a}); tιtk^{a}haxtc (kι̯tka̯haxki^{x}); sa̯wi̍·ɑt (tsa̯wî·'^{ι}).

KITSAI

This Caddoan language is known only as the speech of one small tribe of that name. It was in recent historic times closely affiliated with the Wichita peoples, and Wichitas will be found consistently to give the Wichita name for the Kitsai as one of the bands of the Wichita tribe, although all are aware of the difference in speech. In culture the Kitsai became so similar to Wichita that it is almost impossible today to find characteristics that differentiate them.

The Kitsai language is closely related to both Pawnee and Wichita. Comparisons of the three indicate that it is intermediate to the two others. Many of the Kitsai forms show a striking relation to the Pawnee, while others bear as pronounced a resemblance to Wichita forms. Kitsai resemblances are clearest with South Band Pawnee, and comparison with that Pawnee dialect indicates that these two—South Band Pawnee or Pawnee proper and Kitsai—have been most conservative in retaining old Caddoan forms of the northern Caddoan languages—Pawnee, Kitsai, Wichita.

The Kitsai language is practically extinct today. Of six individuals reputed to know it, one woman knows some simple vocabulary, another seems to understand but is never known to express herself in the language; one man who pretends to speak some Kitsai has its words and forms inextricably confused with a smattering of Pawnee (Wichita being his native speech). Thus only three can

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[1] Op. cit.

[2] On Arikara village names see Gilmore, M. R., Notes on Arikara tribal organization, Indian Notes, vol. 4, no. 4, pp. 344–345, October, 1927.

[3] *Tschihri*, quoted in the Handbook, pt. 2, p. 216, from Maximilian as the Arikara name for the Pawnee, is clearly the Arikara version of tskiri, as here given.

be said to know any Kitsai, and these habitually talk in Wichita and use no English at all. Of these the man can control Kitsai in its simple forms well; one woman who speaks Kitsai and Wichita is not linguistically gifted in either, and is rather subnormal in intelligence; while one woman, Kai Kai, is thoroughly bilingual in Wichita and Kitsai, with a genuine talent for clear thought in language, and it is from her that a knowledge of Kitsai has been obtained and preserved. It may be said that only while she lives is Kitsai still existent; and she is now past 83.

So far as the Kitsai are known to other Caddoans as a group distinct from the Wichita-speaking peoples, they are known by phonetic variants of their own name.[1] The Wichita speak of the language as kí·tsɛ·s, while their own pronunciation is kitsí̯ɑs; their full name tikítsi̯ɑs. The Pawnees call them ki·tsas. Their own name is said by Kai Kai to mean "going in wet sand"; while the Pawnees translate their version of it as "water turtle."

The Kitsai designate the various groups of the Wichita by the regular Wichita band names, and the Pawnees as awá̯hi, the same name as that used by the Wichita for the Pawnee.

WICHITA

The Wichita language is spoken by eight of the nine bands of the Wichita tribe, all bands save the tikítsɛ·s or Kitsai. Today it consists of one dialect only, and there is no evidence in the speech as used by different Wichitas of former subdivision or divergence. But by tradition, and some casually remembered words and expressions, it seems probable that at least two of the Wichita bands spoke Wichita that was dialectically divergent to a minor degree.

Information obtained and cross-checked with a number of informants yielded the following list of former Wichita bands. It is probably as complete and accurate a list as can be secured at this late date: toka′nɛ, ɩsí·s, tiwá·, ɩtá·, ki̯riki̯rí·s, ɑkwi·ts, tawakɑ̯rú^{w}‘, wéku’ (and tikítsɛ·s). James Mooney[2] lists nine bands, some of which are immediately identifiable with those above: thus kɩtikɩtish (kɩrɩkɩrish) for ki̯riki̯rí·s; akwesh for ɑkwi·ts; tawakoni (tawakarehu) for tawakɑ̯rú^{w}‘; and waco for wéku’. "kirishkitsu", although it is evidently intended for a Wichita-speaking group, may be an old Wichita name for the tikítsɛ·s: in which case it is kí̯k’i·skitsu, meaning "water turtles", and forming an analogy to the meaning which

[1] Unless "kirishkitsu", as mentioned below is the old Wichita name for the Kitsai.

[2] Handbook, pt. 2, p. 947.

is given by the Pawnee proper for the Kitsai name. "Tawehash" may be a variant of tiwá·, possibly resulting from dialectic differences of pronunciation; the synonymy of the Handbook includes several Spanish variants, such as Teguayos, which seem to support this view.[1] "Yscani," suggested by Mooney on the evidence of Bolton as possibly another name for the wéku', an idea which is supported by the disappearance from historical records of the name Yscani at the time wéku' makes its appearance, nevertheless accords too closely with toka'nɛ or ɩsí·s or both taken together. Further the reason for the late appearance of wéku' seems more probably as suggested below. Of Mooney's names, we have no record of "kishkat" and "asidahetch". The words can however be recognized as good Caddoan. Of the names in the list above Mooney lacks any suggestion of ɩtá·. One old informant suggested as an additional band name nɛtɛkwɷ'·ka̯rikʷˢ, "the laughing people", but others claimed this was the name of a village, not of a band.

Traditions and statements of informants today agree that the tawaka̯rúʷʻ and wéku' (towaconi and waco) spoke somewhat differently from people of the Wichita bands, although mutual intelligibility is affirmed. Discussion of the speech of these two bands with contemporary Wichitas arouses laughter, apparently because many of the turns of expression of the tawaka̯rúʷʻ and wéku' speech as grasped in Wichita phonetics have different meanings from those intended, and sound ludicrous. One or two expressions still recalled, though how accurately can not be determined, support this view, indicating a real dialectic difference which has been lost: a few others suggest as more probable difference of idiomatic usage as the distinction between the speech of these two bands and that of the others. As the wéku' and tawaka̯rúʷʻ were the westernmost groups of the Wichita, and somewhat apart from the others, it seems reasonable that local differences should have existed.

The name generally given as the Wichita name for themselves is kɩrikɩrí·s, the name of one of the bands. The origin of the term Wichita is open to some dispute. One tradition is that the first native met by a white man, asked who he was, replied "wɩts ɩtá", "a man, that's what I am", whence the name. The suggestion is sound linguistically; but in view of informants' statements that ɩtá· was the name of a Wichita band, it may be that Wichita is a combination of wɩts—"man", and ɩtá·—this group name, viz., ɩtá·—

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[1] Handbook, pt. 2, pp. 705–706.

men.[1] Actually there seems no Wichita name for the tribe as a whole.

Meanings have not been obtained for all the band names of the Wichita, and the full understanding of these must await thorough analysis of the Wichita language.

ιsí·s means "awls", and was used for this group of the people because of their skill in the use of awls.

ɑkwi·ts is "dull teeth", said to refer to the fact that the old people of the band had dull teeth.

tawakɑ̯rú^w' "neck of land in the water" refers to the character of the place where these people lived.

kι̯rikι̯rí·s "coon eyes", "raccoon eyes", is understood by the Pawnee proper as kι̯rikū·ruks "bear eyes".

wéku' is said by informants to be derived from we̯hiko, which latter is evidently the Wichita rendition of Mexico as pronounced by the Spanish; it was used for the people of this band because, according to tradition, they were always fighting with the Mexicans. They are spoken of as "Indians who were always scouting around". They are said to have originally been part of the tawakɑ̯rú^w', without a village to themselves, but later to have lived independently. If this origin of the name be correct, it is clearly not an ancient Wichita or Caddoan name, which may explain why it does not appear unmistakably in historical records until after 1820.[2]

The Wichita refer to the Pawnee as awa'hi; apparently this is the same designation as the awáhu of the Arikara. There is no evidence that use of awa'hi is recent; but the significance of this identity of Wichita and Arikara names for the Pawnee, in view of the traditional explanation of its meaning as given by the Arikara, must await further study.

It seems possible that this awa'hi is what was intended by the "Harahey" and "Arahey" of the Spanish accounts of Coronado's expedition into Wichita and Pawnee country.[3] The country to which Coronado was led has been identified as Wichita country, and there the people told the Spaniards about a land and people to

[1] Nevertheless the same kind of misunderstanding occurred in the case of the Pawnee. Grinnell, p. 240, says of the Pawnees, "the southern tribes call them pi-ta'-da". This is evidently pí·tɑ̯tɑt which means "man, that's what I am", and phonetically and morphologically is exactly equivalent to the Wichita wιts ι̯tá.

[2] Cf. Handbook, pt. 2, p. 887.

[3] James R. Murie some years ago made this same suggestion to F. W. Hodge. See Amer. Anthrop., n. s., vol. 17, pp. 215–216, 1915.

the north, Harahey, whose customs and houses were similar to their own; evidently they spoke of the awa'hi.[1]

CADDO

Caddo, as spoken today, is essentially the language of the kado'-ạdátc'ᵘ band, which seems to have gradually eliminated whatever former dialectic differentiation existed, in favor of a common speech. All traditions of older living Caddos point to a time when the various bands lived apart and each spoke a somewhat divergent dialect; some even claim that these were not mutually intelligible, but there is little evidence for this view.

There were in all eight branches of the Caddo tribe which are remembered by present day natives as speaking Caddoan: ha͡ina͡i, nabada͡ítcu, nada'rko, nacịdóc, ya't'ɑs, nak'ohọdo'tsi, ha'i·c, kayɑma͡ici, and kado'ạdátc'ᵘ. To these should probably be added the Adai.

James Mooney lists 12 bands of the Caddo confederacy.[2] Of these he identifies one (Imaha) as a small band of Kwapa, and another (Yowani) as a band of Choctaw. Of the remaining 10, 9 will be found readily identifiable with the names in the above list; only Mooney's "Nakanawan" is absent. Mooney states that the kado'ạdátcu'ᵘ, nada'rko, and ha͡ina͡i called themselves collectively hasinai "our own people". While this may have been used by Caddos for some groups of the people collectively, it seems doubtful that it included just these three, since nabada͡ítcu and ha͡ina͡i are closely associated together as speaking the same dialect, and as forming the most divergent branch of the Caddo.

According to informants' statements, at one time all bands of the Caddo spoke divergent dialects, save the ha͡ina͡i and nabada͡ítcu, whose speech was identical; in fact they claim that the nabada͡ítcu was a branch of the Hainai rather than of the Caddo in general. Hainai was the largest band numerically, kado'ạdátcu'ᵘ the second largest.

The divergence of Hainai dialectically from Caddo proper is supported by a little evidence still obtainable in the form of a few remembered differences in words. These are of two types: slight phonetic differences of a dialectic character; and complete difference of word. In some cases the latter type of difference suggests adoption of foreign words, particularly of Spanish words; such occur

[1] Nevertheless the possible relation of "harahey" to the Arikara "star-rah-he", as above mentioned, cannot as yet be dismissed.

[2] 14th Ann. Rep., Bur. Amer. Ethnol., p. 1092, 1897.

prominently for words which must be relatively recent in use, such as the word for horse. In Caddo proper, the vocabulary shows instances of multiple synonymy, and more than one word for the same object, which may prove to have resulted from two factors: adoption of foreign words, as Spanish, and preservation of usages of a number of the Caddo bands in the contemporary Caddo proper. Hainai kinship terms and usages also differ from those of Caddo proper.

Adai is preserved to us in the form of brief vocabularies.[1] Those words which can be summarily identified with Caddoan stems indicate that Adai is probably a divergent dialect of the Caddo.

Linguistically the Caddo is most divergent of the Caddoan languages in three directions: phonetics, vocabulary and morphology. In vocabulary, it shows, as above suggested, a mixture of stems and words from a number of alien sources.

NOTE ON NAMES APPEARING IN THE CORONADO NARRATIVE[2]

It is well known that Coronado, while in the Pueblos in 1540–1541, heard from captive Plains Indians of the lands to the east; and that "Turk", his guide into the Plains, was probably a Pawnee. The name Quivira, used in the Spanish accounts for the land along the eastern Plains to which they were led, is evidently the Pawnee word kíwi̧ra. This word is not one which was ever employed as a name for any definite tribe or country. It means "different", "strange". It seems plausible that Turk in trying to describe to the Spaniards the country to the east, explained "it's different", etc., meaning different as to flora, fauna and ways of life from the pueblo country in which the Spaniards then were. If this was the case, kíwi̧ra would have been correctly used for his meaning.

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[1] Latham, R. G., Opuscula, pp. 402–405 (50 words), London, 1860.

Latham, R. G., Natural history of the varieties of Man, pp. 366–367 (48 words), London, 1850.

Latham, R. G., Elements of comparative philology, pp. 468–470 (45 words), London, 1862.

Gallatin, A., Synopsis of the Indian Tribes of North America, Amer. Antiq. Soc. Trans. (135 words from the Sibley manuscript).

Trans. Amer. Ethnol. Soc., vol. 2, pt. 1, pp. 95 and 97 (60 words from Sibley), 1848.

Gatschet, A. S., A migration legend of the Creek Indians, p. 42, Philadelphia, 1884. Refers to a list of 300 words gathered in 1802 by Martin Duralde, which is now in the Library of the American Philosophical Society in Philadelphia. We have not seen this last Adai vocabulary.

[2] Winship, G. P., The Coronado expedition, 1540-1542, 14th Ann. Rep., Bur. Amer. Ethnol., pt. 1, 1896.

While in Kansas, the Coronado expedition was told by the natives about a land and people to the north similar in ways of life to themselves. The Spaniards recorded the name given them as Harahey or Arahey. We have discussed the possible derivations of this name under Arikara and Wichita above. It has generally been accepted that the country to which Turk first brought the Spaniards was Wichita country. No doubt the statements of Spanish accounts that the houses were made of grass is part of this evidence. But there survives among the Pawnees a tradition to the effect that long ago their lodges were grass-covered, and that only as they came into colder northern regions did they cover the lodges with mud. Thus it seems to us possible that it was to a relatively southern group of Pawnee villages that Turk led the Spaniards, and that Harahey was intended to refer to the Arikara further north. This cannot be substantiated, however, by present usage of the Pawnee for the Arikara.

Coronado and his men were told that the nation was ruled by Tatarrax. This is certainly a Pawnee word, tátạra·k—forming the first person inclusive plural of all Pawnee verbs. The most probable form for which it was intended is tátạra·k^{ux}, "one of us is present (sitting)". It is, however, not a personal name.[1]

Ysopete, the name of the Plains Indian who supplanted Turk in the confidence of the Spaniards, seems to be a Wichita word.

[1] James R. Murie considered Tatarrax as probably intended for táturash (tá·tụrɑs), "I found it", stating that a Pawnee with that name died after the removal of the tribe to Oklahoma. See note by F. W. Hodge in Amer. Anthrop. n. s., vol. 17, pp. 215–216, 1915.

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[1] Acknowledgment is due the Council for Research in the Humanities, Columbia University, whose grant made possible a great part of the museum study on which this treatment is based; the work has been completed as Fellow of the National Research Council.

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INTRODUCTION

The following notes on prehistoric basketry of the Southwest are not an exhaustive treatment. They include references to the material with which I have come in contact and are a first attempt at classification.

The material is more or less uneven. It includes well-documented specimens from sites which have been thoroughly excavated, sporadic specimens which have been obtained from sites of undoubted importance but not as yet thoroughly worked out, and some general and miscellaneous collections of important specimens, some of which cannot be definitely ascribed to a particular site or archeological period. In the latter category would fall the Wetherill and the McLloyd and Graham collections and the collection in the San Diego Museum which can be referred only to generalized geographical locations. I have listed the material by sites so far as it was possible, and included under site classifications whatever in the above general collections could be localized.

ABBREVIATIONS

In referring to collections in various museums the following abbreviations are used:

A.M.N.H. ....American Museum of Natural History, New York, N. Y.
B.M. ....Brooklyn Museum, Brooklyn, N. Y.
F.M.N.H. ....Field Museum of Natural History, Chicago, Ill.
M.A.I., H.F. ....Museum of the American Indian, Heye Foundation, New York, N. Y.
S.D.M. ....San Diego Museum, San Diego, Calif.
U.C.M. ....University of California Museum, Berkeley, Calif.
U.P.M. ....University Museum, University of Pennsylvania, Philadelphia, Pa.
U.S.N.M. ....United States National Museum, Washington, D. C.

THE SAN JUAN AREA

Sites in Navaho National Monument

MARSH PASS, ARIZ., AND ASSOCIATED SITES [1]

Culture horizons: Basket Maker, Pueblo I, and Cliff Dweller.

From caves, ruins, and burials in Marsh Pass and in Sagiotsosi [2] and Sayodneechee canyons, Kidder and Guernsey have unearthed great numbers of basketry remains. These are the type sites for basketry of Basket Maker type technique. Two periods are well represented in the basketry recovered from this location, Basket Maker and later Cliff Dweller, and in addition a single specimen from Cave 1, Segi Canyon, represents the intermediate, Pueblo I or pre-Pueblo period.[3]

The Basket Maker basketry found, with the exception of one twill-plaited specimen from White Dog Cave and another which may be matting from Cave 1, Kinboko in Marsh Pass, was exclusively coiled ware. Basketry specimens were so abundant in Basket Maker caves

[1] Kidder and Guernsey; Guernsey and Kidder. Statements on the material from these sites are based upon these publications; I have also had the opportunity of examining specimens in the Peabody Museum.

[2] Besides the Kidder and Guernsey material, a coiled burden basket, a cradle basket, and a bowl are illustrated in Cummings, 1910, p. 34, as probably from this location; and another cradle basket is mentioned from Bat-woman's House, Cummings, 1915, pp. 281-282.

[3] This basket is pictured on pl. 13, Guernsey, 1931. The specimen is in the Peabody Museum.

as to constitute almost one third of the specimens found. The shapes of Basket Maker work fall into five classes: trays (the commonest form), bowls, carrying baskets, water baskets, and trinket baskets. Designs are all in black.

The technique of the coiling found in this Basket Maker material can be summarized as follows: The work is consistently done toward the left of the basket maker (fig. 1*a*, *b*). Most of the work is done on the concave surface; some globular forms are worked on the concave surface to the shoulder and thence on the convex surface from shoulder to rim; a few globular forms are worked entirely on the convex surface (fig. 1*b*). The work being consistently in the left direction, concave work surface implies that the stitching is done at the far edge of the circumference (fig. 1*a*), while convex work surface implies that the stitching is done on the near edge of the circumference

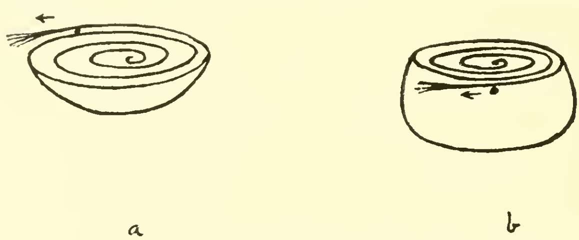

FIG. 1.—*a*. Coiled basket with counter-clockwise spiral, worked on the concave surface, toward the left of the worker. *b*. Coiled basket with clockwise spiral, worked on the convex surface, toward the left of the worker. The dot indicates the place on the circumference where the work is done.

(fig. 1*b*). Descriptively, baskets worked on the concave work surface show a counterclockwise spiral (fig. 1*a*); those worked on the convex work surface show a clockwise spiral (fig. 1*b*). Throughout Basket Maker coiling the stitches are noninterlocking (figs. 2, 3).[1] The predominant or typical foundation is two-rod-and-bundle-triangular (fig. 2); occasional specimens were found to have a single-rod-surrounded-by-fiber foundation (fig. 3).

The above description with respect to the two-rod-and-bundle-triangular foundation baskets defines technically what I refer to throughout this paper as Basket Maker type coiling.

Twill-plaiting.—One specimen in twill-plaiting from White Dog Cave[2] is in over-2-under-2 weave with the bottom unwoven; it is probable that the basket was made downward from the rim.[3]

[1] Kidder and Guernsey, pp. 168-169, fig. 80.

[2] Guernsey and Kidder, p. 63, and pl. 23*b*, opposite p. 62.

[3] Compare the specimen of twill-plaiting from Canyon del Muerto described elsewhere in this paper, and the jar-shaped specimen from Canyon de Chelly.

The Pueblo I or pre-Pueblo period is represented by a single specimen, a well-preserved coiled burden basket from Cave 1, Segi Canyon. The walls are almost vertical for about two thirds of the height, forming a narrow ellipse in cross-section, the upper third to the rim showing a very decided flare. The coiling is of the regular Basket Maker type.

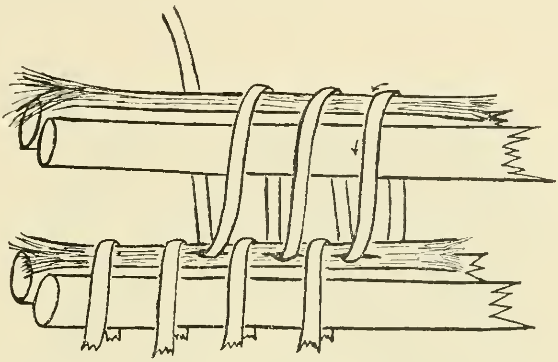

FIG. 2.—Coiling, with noninterlocking stitches, on a two-rod-and-bundle-triangular foundation. (This is the typical Basket Maker technique.)

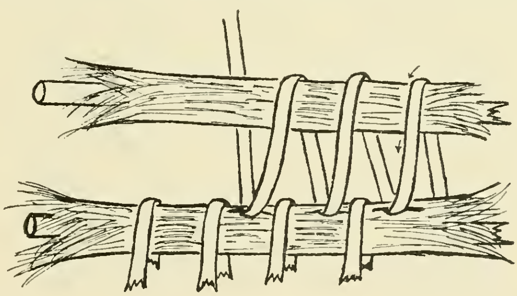

FIG. 3.—Coiling, with noninterlocking stitches, on a single-rod-surrounded-by-fiber foundation. (This is a variant of the Basket Maker type technique.)

Cliff Dweller material[1] includes fragments of shallow coiled trays and yucca-ring baskets. The yucca-ring baskets are predominant, the coiling being far rarer than in the Basket Maker sites.

The technique of Cliff Dweller coiling is identical with that found in Basket Maker trays, the two types being distinguishable only in texture. In Basket Maker material, the stitch measurements range

Guernsey and Kidder, p. 63, also point out the contrast of this type of twill-plaited basket with the yucca-ring baskets which are made from the bottom center up (fig. 4).

[1] Kidder and Guernsey, pp. 108-110.

from $2\frac{1}{2}$ coils and 6 to 7 stitches per inch (the coarsest) to 7 coils and 12 stitches per inch (the finest), the great majority of specimens having 5 coils and 9 to 11 stitches per inch. The stitches are spaced so that the foundation shows between stitches. In Cliff Dweller material, the stitch measurements range from 4 to $4\frac{1}{2}$ coils and 8 to 10 stitches per inch (the coarsest) to 5 coils and 17 stitches per inch (the finest). In all Cliff Dweller material the foundation elements are entirely concealed. In general, the sewing splints used by the Cliff Dwellers are considerably finer than those of the Basket Makers.

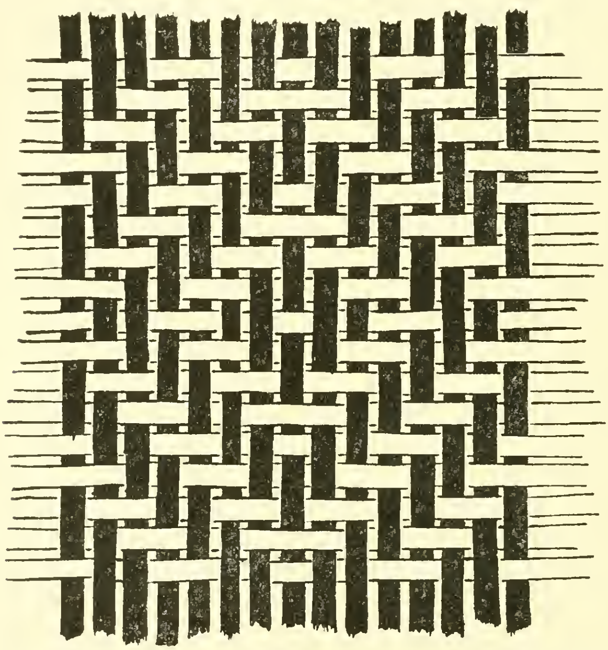

FIG. 4.—Central pattern of a yucca-ring basket in over-2-under-2 twill-plaiting with concentric diamond pattern, illustrating the type of twill-plaited basket made from the center bottom outward. (This is the typical Cliff Dweller technique.)

The yucca-ring baskets are made in over-2-under-2 twill-plaiting of yucca strands as a mat and fastened to a wooden rim ring. All the yucca-ring baskets from this site had concentric diamond patterns; one fragment indicated use of strands of two colors (fig. 4).[1]

BETATAKIN

There are three specimens of coiled work from Betatakin in the United States National Museum. One is a fragmentary basket

[1] Kidder and Guernsey, p. 109.

bottom,[1] the other two are bowls.[2] All are in Basket Maker type coiling on two-rod-and-bundle-triangular foundation (fig. 2). No design is evident. The stitch measurements are similar, one being 5 coils, 12 stitches to the inch, another 5 coils, 11 stitches, and the third 4½ coils, 11 stitches.

A yucca-ring basket collected by Fewkes at this site is made in over-2-under-2 weave with a concentric diamond pattern in one color.[3]

CRADLE HOUSE

This ruin was named after the find there by W. B. Douglass of a Cliff Dweller cradle, with which was associated a pair of infant sandals.[4] The basket is of burden-basket form with a deep cleft in the bottom; it is made in Basket Maker type coiling on a two-rod-and-bundle triangular foundation with noninterlocking stitches.

Fewkes, 1911a, mentions another specimen, practically identical with the above, which was found by E. B. Wallace in San Juan County, Utah, not far from the Colorado River. This, according to Fewkes, finally reached the Field Museum of Natural History. I find that this is the specimen which is now in the University of Pennsylvania Museum.[5] I have not seen the basket figured by Fewkes, but I have seen the Pennsylvania specimen and another in the San Diego Museum.[6] These are so nearly identical that Fewkes' comment would apply, " that the two (three) might have been made by the same woman." I have examined both specimens in detail. They are so much alike that it is sufficient to give the facts on the San Diego basket.

The San Diego basket comes from " a cave in southern Utah." It is about in the same condition as the one figured by Fewkes, the design somewhat more faded. The measurements are: 21 inches high (14½ inches from rim to leg, 6½ inches for the legs), and the oval mouth is 9 by 6 inches.[7] It is coiled on a two-rod-and-bundle-triangular

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[1] U.S.N.M. No. 270259.

[2] U.S.N.M. No. 312393: I examined this specimen through the courtesy of N. M. Judd; U.S.N.M. No. 270258, Fewkes.

[3] U.S.N.M. No. 270252, Fewkes.

[4] Fewkes, 1911a, pp. 29, 30; pls. 19, 20, and 21.

[5] The University Museum, University of Pennsylvania, has published a post-card photograph of this specimen. Farabee, p. 202, says: "The basket was found in a cliff house in Moki Canyon, San Juan County, Utah, near the Colorado line. In 1904 it was exhibited at the World's Fair, St. Louis. Thereafter it was on loan at the Field Museum until finally purchased by the University Museum in 1908."

[6] S.D.M. No. 4759.

[7] Compare Fewkes, 1911a, pl. 19, "Dimensions: length 22 inches, breadth 9 inches; diameter 6 inches."

foundation, with noninterlocking stitches, and is apparently worked toward the left of the worker on the concave work surface. The stitch measurements are 4 plus coils and 12 stitches per inch. At the finish there are about 2 inches of false braid stitching. The design, practically identical with the Fewkes and Pennsylvania specimens, is in red and black.

Two other specimens of this type are referred to by Cummings.[1] One, "found in a pot hole in one of the gulches of Sagi at Sosi Canyon," the other from a room in Bat-woman House.

Besides these specimens I have seen miniature coiled baskets of this shape and workmanship; the texture of the stitching and foundation was much finer. Evidently such a miniature is a *tour de force*. These miniatures I saw through the courtesy of N. M. Judd of the United States National Museum; I understand they are part of his material from Pueblo Bonito.

Interesting in this connection is also a specimen in the Museum of the American Indian, Heye Foundation, which is from a cave in Grand Gulch, Utah.[2] It is a miniature basket, like a toy, made in twill-plaiting in under-2-over-2 weave, in a shape that suggests a cradle basket; that is, it has a body and two legs.

Canyon del Muerto

Culture horizons: Basket Maker III, Post Basket Maker, and Pueblo III.

E. H. Morris found large numbers of baskets at several sites in Canyon del Muerto in Arizona. His collections are now in the American Museum of Natural History. In addition, there is the large beautiful plaque in the United States National Museum.[3]

In the basketry from the earlier horizons, two techniques are found, close coiling and twill-plaiting. There is evidence in the pottery remains from the site of the presence of a second type of coiling there, sifter coiling.

Close coiling.—All the coiled basketry from this site is decidedly uniform in texture and technique. The technique is Basket Maker type (figs. 1 and 2), namely, with counterclockwise spiral, made on the concave work surface toward the left of the worker, with noninterlocking stitches. There are differences in the handling of globu-

[1] Cummings, 1910, illustration p. 34; and Cummings, 1915, pp. 281-282.

[2] M.A.I., H.F. No. 5/1790. Cf. elsewhere in this paper under Grand Gulch.

[3] U.S.N.M. No. 231776. It is a flat, round, coiled plaque secured by the Bureau of Indian Affairs; Culin, 24th Ann. Rep. Bur. Amer. Ethnol., includes a photograph of this basket as frontispiece.

lar baskets.[1] In foundation, most of the baskets are made on a two-rod-and-bundle-triangular foundation (fig. 2), occasional specimens on two-rod-and-reed-triangular foundation.[2] The stitching runs about 5 coils and 9 stitches to the inch.[3]

In shape the coiled baskets include trays, bowls, globular baskets, large conical burden baskets, and a number of burden baskets of a different type—with almost vertical walls, flaring somewhat at the mouth, and with bottom and cross-section elliptical. The dimensions of the ellipse are about 3 : 1.[4]

Designs that occur on these baskets are in black, or in red and black. The plaque in the United States National Museum has a beautiful realistic figure of a frog painted in blue on the non-work surface.

Sifter coiling.—A basket-moulded sherd[5] from this site shows in reverse sifter coiling which resembles the Canyon de Chelly specimen (fig. 6).[6]

Twill-plaiting.—From this site there is a cylindrical basket of yucca, woven in over-2-under-2 twill-plaiting. At the mouth, the shoulder, and the bottom is a row of twining. The bottom is open, and the strands of yucca from the body are unwoven and lie loosely across the bottom. It seems probable that the basket was woven from the mouth down.[7]

Material of the Pueblo III period[8] from this site includes a coiled bowl and four yucca-ring baskets. The coiled bowl has almost vertical walls, and is finely stitched in Basket Maker type technique on a two-

[1] See above, p. 4. Cf. Amer. Anthrop., vol. 32, p. 386.

[2] For example, the U.S.N.M. plaque, as above.

[3] Morris, 1927, includes, pp. 195, 196, photographs of seven trays with the A.M.N.H. numbers. Fig. 43*e*, p. 196, illustrates the average texture. The other photographed specimens show rather finer stitching than the average of the coiled work from this site.

[4] For example A.M.N.H. Nos. 29.1/8442 and 29.1/8343. All the specimens of this type of burden basket were found by Morris at one Basket Maker III site, in association with the mummy of a child.

[5] Morris, 1927, p. 138, fig. 1*a*.

[6] B.M. No. 11913, discussed elsewhere in this paper under Canyon de Chelly.

[7] A.M.N.H. No. 29.1/1549.

[8] These baskets were found by E. H. Morris in a burial cist which contained a mummy, pottery of Mesa Verde type, and other objects. The entire contents of the burial cist are on exhibit in the American Museum of Natural History. According to the label, "the only ruin in the locality characterized by such pottery is a large pueblo half a mile distant, from which presumably the body was brought for interment. The burial dates from the last ancient occupation of Canyon del Muerto, probably around 1000 A. D."

rod-and-bundle-triangular foundation (fig. 2). The closeness of the texture corresponds to what I have called above Cliff Dweller. Of the four yucca-ring baskets, two are large and two are small. Two are made in over-2-under-2 weave with plain diagonal pattern; two in over-3-under-3 weave have a concentric diamond pattern (fig. 4).

Canyon de Chelly

Many years ago the Days secured cultural material from Canyon de Chelly, now in the Brooklyn Museum. Included is basketry in two techniques, coiling and twill-plaiting. The coiling is of two types, close coiling and sifter coiling. Of three examples of close coiling analyzed, a burden basket and a vertical-sided shallow bowl are Basket Maker type (fig. 2) in all particulars,[1] while the third specimen, a

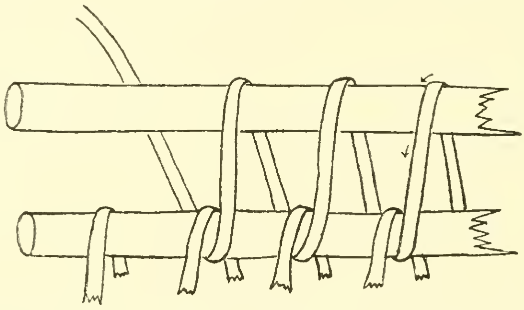

Fig. 5.—Coiling, with interlocking stitches, on a single-rod foundation.

bowl, is atypical in that it has interlocking stitches and is made on a single-rod foundation (fig. 5).[2] This basket is one of the occasional baskets in this technique found associated with Basket Maker type material. The vertical-sided shallow bowl shows 4 coils, 7 to 9 stitches to the inch.

A specimen of sifter coiling is illustrated in Figure 6.[3] It is made on a two-rod-and-bundle-triangular foundation with noninterlocking stitches. The thread is wrapped about the foundation of the course of coiling in work; at intervals it is caught in the foundation of the course below, and then wrapped about itself between the courses. In principle, this method is of the same type as the sifter-coiling techniques found in specimens from the Hazzard Collection (fig. 7) and from Bear Creek on Blue River (fig. 17). This Canyon de Chelly technique, as will be seen from a comparison of Figures 6 and 7, differs from that

[1] B.M. No. 11912; the other is unnumbered. This burden basket has almost vertical walls and is oval in cross-section.

[2] B.M. No. 10904.

[3] B.M. No. 11913.

of the specimen in the Hazzard Collection in that the "standing-part" of the fastening stitch, instead of being inserted under the wrapping of the completed course of coiling below, is set between two wrappings and put through the foundation of the completed course of coiling

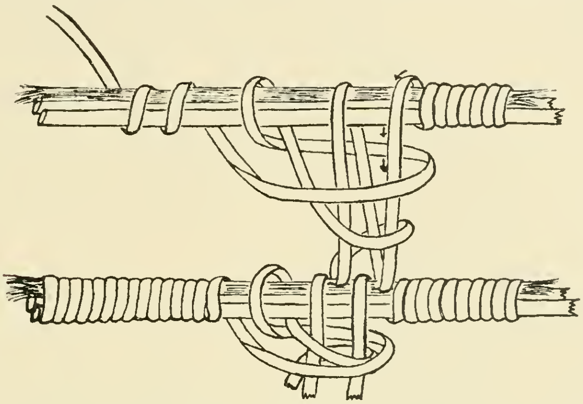

FIG. 6.—Sifter coiling, on two-rod-and-bundle-triangular foundation, with noninterlocking stitches. Type found in Canyon de Chelly (variant of type B).

below; in wrapping around the "standing-part" of the fastening stitch, the thread is wrapped twice instead of once; and finally the fastening stitches are not made in alternate order, but one directly above the other so that they appear as radial lines on the sides.

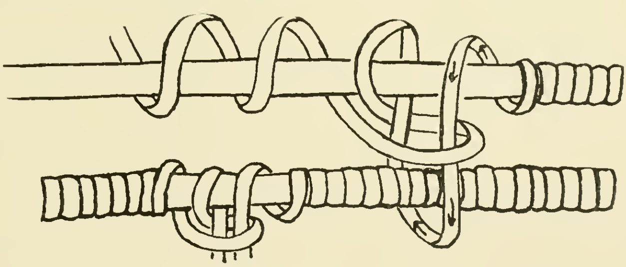

FIG. 7.—Sifter coiling, type B: Hazzard collection.

The twill-plaiting technique is found in yucca-ring baskets in over-2-under-2 weave. A typical specimen[1] has a concentric diamond pattern (fig. 4). Another has a plain diagonal twilled design.[2] A third specimen is jar-shaped, was probably made from the mouth to the bottom without closing the bottom, and has a false bottom of bunched yucca leaves fastened together by twining.[3]

[1] B.M. No. 11942.

[2] B.M. No. 11941; found with the mummy of a child in White House. A. E. Douglass dates White House 1060-1275 A. D.

[3] B.M. No. 11918.

Southern Utah Sites

GRAND GULCH

Considerable basketry and fragments have been found in Grand Gulch. The material I have seen from this site is in the American Museum of Natural History and the Museum of the American Indian, Heye Foundation. The basketry includes work in close coiling, sifter coiling, and twill-plaiting techniques.

Close coiling.—Seventeen complete baskets and a number of basket-bottoms consistently show the following technique: Concave work surface, counterclockwise spiral, worked toward the left of the worker, noninterlocking stitches, on a two-rod-and-bundle-triangular foundation (Basket Maker type, figs. 1*a*, 2).[1]

The shapes of these baskets include trays, deeper round bowls, bowls with flat bottoms and straight slanting walls, baskets with flat bottoms and straight slanting walls which are oval in cross-section, large conical burden baskets, and globular baskets. Decorations are in red and black or in all black. These baskets are all coarse in texture, of the Basket Maker type of texture (with foundation elements appearing between the stitches) rather than of the Cliff Dweller texture.

Three baskets from Grand Gulch, of which two are small bowls and one a globular form, are made on a one-rod foundation with interlocking stitches (fig. 5): the bowls are made on the concave work surface, have a counterclockwise spiral, and were made toward the left of the worker (fig. 1*a*); the globular basket was made on the convex work surface and has a clockwise spiral; it was also made toward the left of the worker (fig. 1*b*).[2]

Sifter coiling.—One basket in sifter coiling comes from this site. Around the rim are several courses of coiling on a one-rod foundation with interlocking stitches; in technical traits this one-rod coiling is identical with that of the two bowls above mentioned, which are on one-rod foundation. The sifter technique is identical with that in a sifter basket from Kane County, Utah (fig. 8).[3]

Twill-plaiting.—Six baskets examined from this site, in over-2-under-2 weave, fall into two groups:

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[1] Mason, pls. 205-211, and Pepper, 1902, both picture many of the Grand Gulch specimens which are in the American Museum of Natural History. The museum numbers are: A.M.N.H. No. H-12264, 12270, 12273, 12275, 12276, 12279, 12315, 13133, 13161, 13505, 13507, 13509, 13511, 13515, 13526, 13527, 13928, 13960.

[2] M.A.I., H.F. Nos. 5/5350, 5/5352; A.M.N.H. No. H/13955.

[3] Now in the American Museum of Natural History. See Amer. Anthrop., vol. 32; pp. 484 and 488, fig. 18*a*. See also Mason, p. 257 and pl. 31.

Two globular baskets made of yucca leaves are of the type that is probably made from the mouth down, leaving the bottom open; one of these has a small mat fastened by twining to the bottom opening and a twill-plaited collar attached.[1]

Four baskets of yucca made from the center bottom up (similar in this to the yucca-ring baskets) include three bowl shapes with slightly constricted necks. At the mouth, they are finished by bending the edge over a rod and fastening with a row of twining. All have concentric diamond patterns (fig. 4). They differ from yucca-ring baskets in that the body is full and the neck constricted, so that they must have been shaped while weaving as yucca-ring baskets never

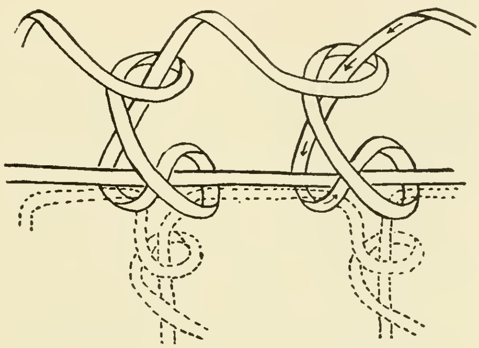

FIG. 8.—Sifter coiling, type A: Kane County.

are. The fourth basket made of yucca leaves is of a form with body and two legs suggesting a cradle basket.[2]

There is also a yucca-ring basket from Grand Gulch now in the American Museum of Natural History.[3]

WHITE CANYON

I have seen a basket in the Museum of the American Indian, from a cave at this location. It is a coiled tray of Basket Maker technique in every particular, with a zigzag design in black[4] (measurements: 6 coils, 13 stitches per inch).

[1] A.M.N.H. No. H/13533, M.A.I., H.F. No. 5/5351. Baskets of this type with bottom unwoven are mentioned in this paper under Marsh Pass, Canyon del Muerto, Canyon de Chelly, and the San Diego collection from southern Utah.

[2] M.A.I., H.F. Nos. 5/5353, 5/5354, 5/5357, 5/1790. On the cradle basket see in this paper under Cradle House.

[3] The basket was found filled with beans. It is thus very doubtful that this is a basket of Basket Maker manufacture. Cf. Guernsey and Kidder, p. 63, footnote 1, who refer to Pepper, p. 23, 1902. Mason, pl. 210, upper picture, center of lower row, illustrates this basket.

[4] M.A.I., H.F. No. 8/3822.

KANE COUNTY

Culture horizon: Basket Maker II.

From Kane County, Utah, Nussbaum[1] secured 30 basketry specimens, which included one in sifter coiling, the rest in close coiling.

All the specimens in close coiling with one exception are consistently Basket Maker type technique on a two-rod-and-bundle-triangular foundation (fig. 2). One basket in close coiling has a foundation of a rod-surrounded-by-fiber, but in all other respects is consistently Basket Maker type work (fig. 3).

The basket in sifter coiling is in a unique technique of stitching illustrated in Figure 8.

BATTLE CANYON (SAN JUAN COUNTY, SOUTHEASTERN UTAH)

There are 11 coiled baskets from this site in the Field Museum. Nine of these are of Basket Maker type coiling, concave work surface, counterclockwise spiral, worked toward the left of the

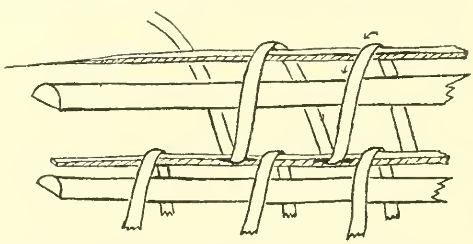

FIG. 9.—Coiling, with noninterlocking stitches; foundation of a split rod with a strip of yucca placed upon it. (Battle Canyon, southeastern Utah.)

worker, noninterlocking stitches, with variations in the foundations. Six baskets have the usual two-rod-and-bundle-triangular foundation (fig. 2),[2] one has a two-rod-and-reed (or strip of yucca blade)-triangular foundation,[3] and two have an unusual foundation: this consists of a round, rather heavy rod split in two, the flat split surface being placed downward. Upon the upper rounded surface of the rod a strip of yucca (?) is placed, through which the stitches are caught (fig. 9).[4] Stitch measurements are: one basket with

[1] Nussbaum. See also my notes on the material from this site in Amer. Anthrop., vol. 32, pp. 484, 486, 487, 488.

[2] F.M.N.H. Nos. 165299, 165293 (found with Basket Maker skull 165294); 165296, 165295, 165285 (these last three found with Basket Maker mummy of a child 165297); 165289 (found containing desiccated mummy of infant 165290).

[3] F.M.N.H. No. 165302 (found with Basket Maker III mummy of child 165303).

[4] F.M.N.H. Nos. 165288, 165292 (both coated with light yellow gum on inside).

4½ coils, 7 stitches per inch; 4 with 5½ coils, 9 stitches per inch; one with 6 coils, 10 stitches; another with 5½ coils, 9 stitches; and the last two with 5½ coils, 10 stitches, and 5½ coils, 13 stitches per inch. These are all round bowl and tray shapes with the exception of one large burden basket (165285), oval in cross-section, which probably had a pointed bottom.

Of the two remaining baskets from this locality, one is unusual in shape and weave and is probably of Pueblo III period as indicated by the associated artifacts.[1] It is oblong, indented on the long sides, having something of a guitar shape, the individual coils being

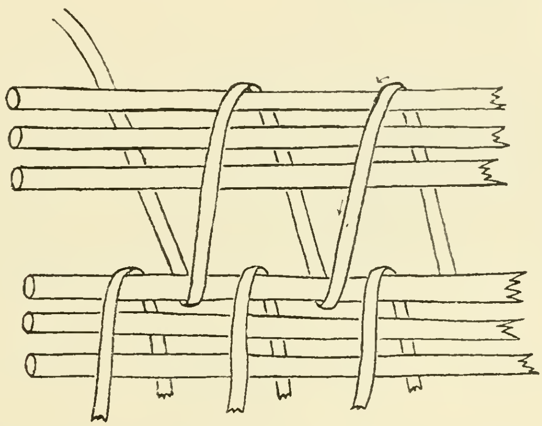

FIG. 10.—Coiling, with noninterlocking stitches, three-rod-vertical foundation.

narrowed at the ends and widened at the sides. The walls of the long sides are bent inward at the rim.

The coiling is of general Basket Maker type: counterclockwise spiral, concave work surface, toward the left of the worker, with noninterlocking stitches; the foundation is three-rod-vertical, the top rod being thinner than the other two (fig. 10). The rim coil has a foundation of two rods placed side by side.

The other basket[2] is a deep round bowl made on a one-rod foundation, with interlocking stitches (fig. 5). The spiral is clockwise, the work surface concave, and the work probably proceeded toward the right of the worker. The decoration is in dark brown bark.

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[1] F.M.N.H. No. 165274, burial cave no. 1.

[2] F.M.N.H. No. 165294.

ALLAN CANYON (SAN JUAN COUNTY, SOUTHEASTERN UTAH)

From this locality are four almost complete coiled fragments of uneven quality. All are of Basket Maker type technique (fig. 2). A large oval burden basket found over a burial is probably Basket Maker II (measurements: 5½ coils, 9 stitches per inch).[1] A large round tray of coarse open texture is made on a rod-surrounded-by-fiber foundation (fig. 3). (Measurements: 5 coils, 7 stitches per inch.) A round shallow bowl has almost vertical walls (measurements: 4½ coils, 13 stitches per inch).[2] A very closely woven almost cylindrical fragment is probably Cliff Dweller[3] (measurements: 4½ coils, 15 stitches per inch).

BUTLER CANYON (SAN JUAN COUNTY, SOUTHEASTERN UTAH)

There are two baskets from this locality, one a coiled basket and the other a small twill-plaited yucca-ring basket. The coiled basket is a small bowl of the usual Basket Maker type weave in all particulars (fig. 2). Measurements: 6 coils, 10 stitches per inch. The design is in red and black.[4] The twill-plaited yucca-ring basket is in over-2-under-2 weave and has a concentric diamond pattern (fig. 4).[5]

Mesa Verde Sites

MESA VERDE PROPER

A specimen found by Fewkes in Mesa Verde National Park, a coiled basketry bottom, now in the United States National Museum, is labeled from Oak Tree House. Fewkes also figures from Spruce Tree House[6] a coiled basketry bottom, and from Cliff Palace a coiled basket hopper and an unfinished coiled plaque.[7]

Nordenskiold figures three coiled specimens from Step House: a cylindrical basket found in a grave, a bowl, and a circular lid found hidden in a refuse heap; and four twill-plaited yucca-ring baskets, three from Spruce Tree House and one from Ruin 9.[8]

In the Wetherill collections there are seven specimens marked as

[1] F.M.N.H. No. 165286 (found over burial, field no. 258).

[2] F.M.N.H. No. 165300.

[3] F.M.N.H. No. 165291.

[4] F.M.N.H. No. 165304.

[5] F.M.N.H. No. 165301.

[6] A. E. Douglass dates Spruce Tree House 1273 A. D. approximately.

[7] Fewkes, 1909, fig. 14, p. 42; 1911, pl. 29 and fig. 2, p. 73.

[8] Nordenskiold, pl. 44, 3, 5, 4; 44, 1, 2; 45, 2, 1.

from a cliff house in Navaho Canyon. Six of these are coiled baskets, and one is a yucca-ring basket.[1]

Coiling.—All the specimens of coiling show noninterlocking stitches, counterclockwise spiral with concave work surface, which means a direction of work toward the left of the worker.[2] While there is some variation in foundations, all but two of the variations agree in having triangular form of three elements.

The specimens from Oak Tree House and Spruce Tree House, the hopper from Cliff Palace, one Wetherill basket from Navaho Canyon, and probably the Nordenskiold material have two-rod-and-bundle-triangular foundation (fig. 2). (Stitch measurements: the Oak Tree

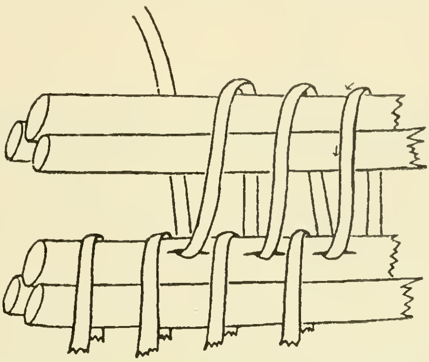

FIG. 11.—Coiling, with noninterlocking stitches on a three-rod-triangular foundation.

House specimen 5 to 6 coils, 22 stitches per inch; the Wetherill specimen 5 plus coils, 14 stitches per inch.)

Three Wetherill specimens from Navaho Canyon have a foundation of two-rod-and-reed-triangular. (Measurements: 4½ coils, 11 to 12 stitches per inch.) One Wetherill Navaho Canyon specimen and apparently the unfinished plaque from Cliff Palace have three-rod-triangular foundation (fig. 11). (Measurements: Wetherill basket, 3 coils, 7 stitches per inch.) Exceptional are one of the above Wetherill specimens, which in addition to work on a two-rod-and-reed-triangular foundation on the rim, has walls made on a single-rod foundation with the stitches noninterlocking (fig. 12); and a little oblong-shaped basket, also Wetherill, which is made on a soft rod which has been split by the sewing stitches passing through it[3] (measurements: 6 plus coils, 10 stitches per inch).

[1] U.P.M., Wetherill Nos. B 51, 55, 54, 42; U.C.M. Nos. 2/3635, 2/3068, 2/3065.

[2] Statements for Spruce Tree House and Cliff Palace specimens figured by Fewkes, 1909, are based on his pictures; I have not seen the specimens.

[3] U.P.M., Wetherill Nos. B 51 and B 42.

Twill-plaiting.—The yucca-ring basket in the Wetherill collections, which is allocated to Navaho Canyon, has a zigzag design carried out in strands of two colors, in under-3-over-3 weave. After the basket was completed, a small plaited collar woven under-1-over-1 was fastened around the rim.[1] Two of the Nordenskiold baskets from Spruce Tree House are of this same type with meander or scroll designs carried out in two colors, having a small plaited collar fastened around the rim.[2] The two others are woven in one color, the specimen from Spruce Tree House having a meander pattern, that from Ruin 9 a concentric diamond pattern (fig. 4). Similar to these, with scroll

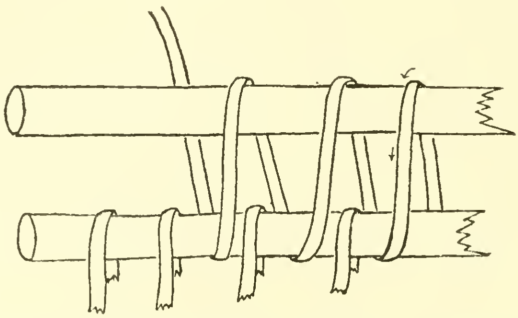

FIG. 12.—Coiling, with noninterlocking stitches, on a single-rod foundation. (This variant of single-rod coiling is of rare occurrence.)

pattern and collar about the rim, is an unallocated yucca-ring basket in the Field Museum; the basket is in over-4-under-4 weave and is 10 inches in diameter.

Shapes.—All the coiled Wetherill specimens (except the one oblong basket, which is similar to small modern pottery paint cups) as well as the Cliff Palace basketry hopper, are bowl and cylindrical shapes; the bowls are similar in size and shape. Of the two cylindrical shapes, one is shallow and one deep.[3] The Nordenskiold coiled material consists of a bowl, a deep cylindrical basket, and a circular lid.

[1] U.C.M. No. 2/3065. There are other specimens of yucca-ring baskets in the Wetherill collections which agree in all the above particulars (although designs vary) with the one described, but these are not allocated. See especially U.C.M. Nos. 3/3071 and 2/3064. In addition, Kidder and Guernsey, p. 109, refer to several Wetherill baskets in two colors as in the Colorado State Museum at Denver.

[2] Nordenskiold, pl. 44, 1 and 2.

[3] U.P.M., Wetherill No. 42, shallow; U.C.M. No. 2/3635.

MANCOS CANYON

In the Wetherill collections there is one basket marked "From Sandal Cliff House, Mancos Canyon" in double coiling on a two-rod-and-bundle-vertical foundation (fig. 13); the stitching runs three coils, 15 stitches to the inch.[1]

From the description of the contents of the Wetherill collections as "from the Cliff Houses in Mancos and tributary canyons of southwestern Colorado," I judge that several other Wetherill specimens with canyon locations are to be associated with this region:

"Lake Canyon": a tray in Basket Maker type coiling but with two-rod-and-reed-triangular foundation (measurements: 4 coils, 12

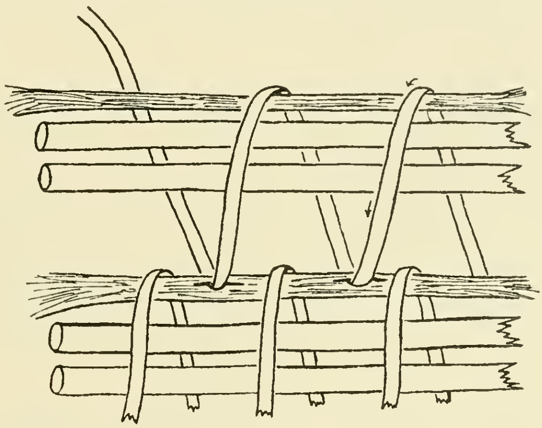

FIG. 13.—Coiling, with noninterlocking stitches, on a two-rod-and-bundle-vertical foundation.

stitches per inch) and a design in black, from a cave; and a basket in sifter coiling of the Kane County type from a ruin (fig. 8).[2] In this sifter basket, it is not clear which is the work surface; if it were worked as usual on the concave surface, the direction of work is toward the right, in which trait it differs from other sifters of this type. (In descriptive terms, this sifter has a clockwise spiral.)

"Red Canyon": One bowl from a cliff house is in Basket Maker type coiling (fig. 2) in all details, with a design in black (measurements: 6 coils, 11 stitches per inch). One yucca-ring basket is in over-3-under-3 weave; the pattern is concentric diamond in black and natural (fig. 4); there is a plaited collar fastened to the outer rim.[3]

[1] U.P.M., Wetherill No. 50 B; cf. Amer. Anthrop., vol. 32, p. 485.

[2] U.P.M., Wetherill No. 20 D, and Wetherill No. 4 D.

[3] U.P.M., Wetherill No. 9 D; U.C.M., No. 3/3071.

"Lost Canyon": Five specimens of coiled ware from this locality include two trays and three bowls.[1] Both trays are Basket Maker type technique on two-rod-and-bundle-triangular foundation (fig. 2) with stitch measurements 5½ coils, 10 plus stitches per inch. The tray from "ruin in Lost Canyon" is 18½ inches in diameter and very shallow; it has a black band design near the rim. The other from "Deep Canyon-Lost Canyon" is 19¾ inches in diameter, 4½ inches deep, with a black horizontal zigzag design; the foundation of the rim coil consists of two rods and a twisted two-ply cord as the apex of the triangular foundation, instead of a bundle of fiber which is used in the body of the basket. The three bowls include one typical Basket Maker type 7½ inches in diameter (stitch measurements: 5 coils, 8 stitches per inch) with black band design; one called "Cliff Dweller" from Lost Canyon in Navaho Canyon with body made in Basket Maker type coiling on a two-rod-and-bundle-triangular foundation (fig. 2), and a set-in bottom made on a one-rod foundation with interlocking stitches (fig. 5); stitch measurements of the body coiling run 10 to 12 stitches, 5 coils to the inch; of the bottom 5 to 6 stitches, 6 rods per inch; and a third, vertical-walled with bottom missing, on a single-rod foundation with noninterlocking stitches (fig. 12), counter clockwise spiral, concave work surface, toward the left of the worker, from cliff house. The stitches are successively a wrapping of the new rod alternating with a regular single-rod stitch (which includes both the new rod and the rod of the course below).

"Colorado River Canyon": *Coiling.*—Two bowls and a bottom fragment in Basket Maker type coil on two-rod-and-bundle-triangular foundation (fig. 2). One bowl 7¾ inches in diameter, 3 inches deep, has a design of black horizontal lines with no apparent plan; stitch measurements are 9 stitches, 5 plus coils per inch, with the workmanship rough and uneven. The other "found in a cave on the Colorado River," diameter of mouth 11 inches, diameter of bottom 5 inches, height 5½ inches (stitch measurements: 5 to 6 coils, 10 stitches per inch), has a twisted fiber string near the rim and remnants of pitch on the inside. The bottom fragment "found in a cliff house" is 4½ inches in diameter (stitch measurements: 5 plus coils, 9 stitches per inch).

Plaiting.—Two yucca-ring baskets include one which has a collar and a design of a double set of concentric squares in black and natural, and another without collar which has a concentric diamond pattern all natural color (fig. 4).[2]

[1] Trays: U.C.M. Nos. 2/3073, 2/3075; Bowls: U.C.M. Nos. 2/3074, 2/3067; U.P.M., Wetherill No. 13 D.

[2] Bowls: U.C.M. No. 2/3069; U.P.M., Wetherill No. 14 D; fragment U.P.M., Wetherill No. 2 D; Yucca-ring baskets: U.C.M. Nos. 2/3064, 2/3063.

JOHNSON CANYON

In cliff dwellings in Johnson Canyon, east of the Mancos River in southwestern Colorado, Morris found fragments of a fine closely coiled basket, a fragment of a twill-plaited basket, and a netlike container made of yucca leaves fastened on a wooden ring.[1] The coiled fragment, from the figure, has a two-rod-and-bundle-triangular foundation, noninterlocking stitches, and was worked toward the left of the worker (fig. 2).

PIEDRA DISTRICT (SOUTHWESTERN COLORADO)

In 1928 Roberts found here in a pit house a small charred fragment of coiling, about 2 inches square, which is now in the United States National Museum.[2] The pit houses according to Roberts are Pueblo I period.

The coiling is Basket Maker type, two-rod-and-bundle-triangular foundation, with noninterlocking stitches (fig. 2). The stitches are sewn quite far apart so that the foundation material is exposed between them; in which characteristic it resembles Basket Maker rather than Cliff Dweller. In connection with the coarseness of texture of this basketry, it is interesting to note Kidder's comments on the early transitional or peripheral character of this site;[3] and that type A house is postulated as earliest at this site.

PUEBLO BONITO, N. MEX.[4]

Culture horizon: Pueblo III.

In Pepper's excavations at Pueblo Bonito, he found basketry remains in two techniques, close coiling and twill-plaiting.[5] In reference to Pepper's ground plan the distribution of the finds was as shown below. The page numbers refer to Pepper, 1920.

Room 2, two coiled baskets, one a meal or gambling tray, "two-rod coil type and has a herringbone edge on the angle of the rim." 1½ feet in diameter (p. 36).

Room 13, fragment of a bowl with evidence of red pigment on both surfaces (p. 69).

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[1] Morris, 1919a. Basketry fragment, pl. 47*c*; plaiting, pl. 52*a*; netted container, pl. 52*b*. I have noted pl. 52*b* as resembling the basketlike containers described and figured by Morris, 1919*b*, fig. 35 and p. 57.

[2] U.S.N.M. No. 348328. See Roberts, pl. 3 and pp. 22 and 74. The specimen was found in his "A" village, 5-E 2 (house and room identification).

[3] Kidder, 1931, pp. 126-127.

[4] Date: (According to A. E. Douglass) 919 (earliest beam cut) to 1130 A. D. (latest beam cut).

[5] Pepper, 1920. The ground plan is fig. 155.

Room 24, a yucca-ring basket (p. 96).

Room 25, fragments and a whole coiled basket "of the three-rod coiled variety"; and a yucca-ring basket with the concentric diamond pattern (p. 107).

Room 32, "one very large basket" (coiled?) (p. 162).

Room 33, a cylindrical basket, 3 inches in diameter and 6 inches in length, covered with turquoise mosaic (coiled?).

Another cylindrical basket, decorated with turquoise and shell beads. (4 cm in diameter and 6 cm in length) (pp. 164 and 169, fig. 71: pp. 174-175).

Room 62, a number of large coiled baskets found covering pockets containing broken potsherds.[1]

I have not seen the specimens referred to in the above. I read Pepper's "two-rod-coiled type" as two-rod-and-bundle-triangular foundation (fig. 2), and his "three-rod-coiled variety" as three-rod-triangular foundation (fig. 11). Thus we have evidence from Pueblo Bonito of coiled basketry, possibly of Basket Maker type, with two types of foundation, and of yucca-ring baskets.[2]

Aztec Ruin, N. Mex (Animas and La Plata Region)

Culture horizon: Great Pueblo period (late Pueblo III).

Morris obtained specimens and other evidence from Aztec indicating that two types of basketry techniques were in use there: coiling and plaiting. There is also a type of basketlike container.[3] The coiled baskets were of three shapes: plaques, bowls, and cylindrical forms. The plaiting included two "carelessly made plaited baskets," and a plaited rush bag. From the illustration the bag is in twill-plaiting in over-2-under-2 weave.

Morris refers to basketlike containers, of which 15 were found. The foundation is a hoop of wood, bound with yucca, to which a lacing of yucca strips is attached to form a loose meshwork within which is a lining of husks.[4]

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[1] Pepper, 1920, pp. 234-235, and p. 227, fig. 100.

[2] Mr. Judd showed me miniature coiled baskets in cylindrical, oblong, and cradle-basket forms, which he has not yet described in print. These are on two-rod-and-bundle-triangular foundation, in technical aspects analogous to the work of the Basket Maker type site (Marsh Pass). They have a false-braid edge. This edging is referred to by Pepper, above, as "herringbone" on the two-rod-and-bundle coiled basket from room 2. Elsewhere in this paper I have compared the shape of Judd's miniature cradle basket to others (under Cradle House, Navaho National Monument).

[3] Morris, 1919b, pp. 54, 56, 57, figs. 32 and 35. A. E. Douglass dates Aztec as about 20 years later than Pueblo Bonito, namely about 1150 A. D.

[4] Morris, 1919b, fig. 35, and p. 57; see also reference in this paper under Johnson Canyon.

Miscellaneous Collections

SOUTHERN UTAH (SAN DIEGO MUSEUM COLLECTION)

In the San Diego Museum, classified as prehistoric baskets from southern Utah, is a collection of seven coiled and three twill-plaited baskets.

Coiling.—Five coiled baskets are Basket Maker type in every particular (fig. 2).[1] The shapes are: two bowls, one very large tray (21¼ inches in diameter), a burden basket, and a cradle basket.[2] All the baskets have about 4 plus coils to the inch, the stitching ranging from 11 to 14 stitches to the inch. The burden basket has two horizontal black zigzag designs; the tray has a band of black near the center. Both tray and burden basket have two lugs of fiber cord on the convex or outside surface. One of the bowl-shaped baskets contains the mummy of a baby wrapped in a rabbit-fur cloak.

One small coiled globular basket is made in Basket Maker type technique but the texture is finer.[3] There are 6 to 7 coils and 14 stitches to the inch near the bottom. The work is finer toward the mouth; it has a plain edge and all the work was done on the convex surface. The mouth is inverted and depressed; six courses at the mouth are made on multiple grass foundation, so that this part of the basket is soft and flexible. A skin covering was put over the mouth and shoulder of the basket and fastened to it by cross-tying of buckskin thongs over the sides and under the bottom. The basket is 5 inches in diameter, 2⅛ inches high and the mouth opening is 2½ inches in diameter.

One coiled bowl is made on a single-rod foundation with interlocking stitches (fig. 5), counterclockwise spiral, concave work surface toward the left of the worker. There is a false braid edge.[4]

Twill-plaiting.—Twill-plaited baskets include two yucca-ring baskets in over-2-under-2 weave, one of which has a concentric diamond pattern (fig. 4),[5] and one globular-shaped basket in over-2-under-2 weave, probably made from the mouth down, with open bottom, over which a square of twill-plaiting has been fastened with one row of twining. This latter basket has two collars of plaiting, the outer one attached extraneously and the inner one a part of the body. There is a fiber drawstring at the mouth.[6]

[1] S.D.M. Nos. 4789, 4756, 4788, 4759.

[2] See also under Cradle House in this paper.

[3] S.D.M. No. 4758, similar in shape to the globular yucca basket below, (S.D.M. No. 4791).

[4] S.D.M. No. 4790.

[5] S.D.M. Nos. 4755, 4762.

[6] S.D.M. No. 4791; baskets of this type and shape with bottom open and collar attached, are described also under Canyon de Chelly and Grand Gulch.

SOUTHERN UTAH AND SOUTHWESTERN COLORADO (WETHERILL, AND McLLOYD AND GRAHAM COLLECTIONS)

Basketry material important from a technical standpoint is contained in the McLloyd and Graham and the Wetherill collections now in the University Museum, University of Pennsylvania, and the University of California Museum. Wherever possible in this paper I have grouped or included specimens from these collections with locations or sites; there remain, however, a number of baskets for which no allocations can be made beyond the general regional one as above.[1]

Coiled basketry.—Basket Maker type coiling on a two-rod-and-bundle-triangular foundation (fig. 2) includes four bowls and one tray. Three undecorated bowls are respectively 8¼ inches in diameter of mouth, 4¼ inches high, 3¼ inches in diameter of bottom; 11 inches in diameter of mouth, 4½ inches in diameter of bottom, 5⅝ inches high; and 13½ inches in diameter of mouth, 8 inches in diameter of bottom, 5 inches high. The stitch measurements are 6 coils, 8 stitches; 5 coils, 7 stitches; 5 coils, 13 plus stitches per inch.[2] A larger bowl, 14¼ inches in diameter of mouth, 9 inches in diameter of bottom, 6 inches high, 4 plus coils, 12 to 13 stitches per inch, with a design in dark brown, an unusual color, has a circular piece of native cloth glued to the outer bottom with pinyon gum.[3] The tray is 16¼ inches in diameter by 4½ inches deep, runs 9 plus stitches, 6 coils to the inch, and has a black zigzag band design.[4]

Cylindrical forms.—These include three pieces, all of relatively fine texture; one piece shows 6 coils, 15 stitches to the inch, while another is very fine, running 5 plus coils, 22 stitches to the inch (Cliff Dweller texture). Two have designs in red and black.[5] There are two oval baskets, one of which is a burden basket. One of the oval baskets has a design in black, while the burden basket has a design in red and

[1] In reference to baskets of this collection in the University of California Museum, which have been classified above under canyon names, Dr. L. M. O'Neale sent me the following note from the catalog: "Baskets shipped from University of Pennsylvania, received August, 1891, named as C. D. Hazzard Collection, divided by G. H. Pepper." Cf. Amer. Anthrop., vol. 32, p. 485, note 58.

[2] U.P.M., Wetherill No. 15 D (found with skeletal remains), Nos. 21 D, 25 D (found with human remains).

[3] U.P.M., Wetherill No. 22 D.

[4] U.P.M., no number.

[5] U.P.M., Wetherill Nos. B 38, and D 21 (found with human remains); the third is U.P.M., no number.

black.[1] One oblong basket, without decoration and of coarse texture, shows a use of both yucca and wood sewing threads in the same basket.[2]

Basket Maker type coiling on a two-rod-and-reed-triangular foundation: two bowls, one tray, one cylindrical shape. The tray is of coarse texture, the other three pieces somewhat finer. One undecorated bowl has red paint adhering to the outside. The other bowl and the tray are decorated in red and black.[3]

There is one shallow, circular fragment of Basket Maker technique on a three-rod-triangular foundation; it is rather coarse in texture.[4]

Interlocking.—Two trays on a two-rod-and-reed-triangular foundation, worked on the concave surface to the left of the worker, show interlocking stitches; the stitch measurements are 5 coils, 10 stitches, and 5 coils, 12 stitches to the inch; one has a decoration in black in an unusual shiny material.[5] Two specimens on a one-rod foundation show interlocking stitches (fig. 5), and are worked on the concave surface to the worker's left. One is a bowl, the second a cylindrical piece, with an unusual embroidery decoration.[6]

Sifter coiling.—There is one sifter basket in these collections. The technique is illustrated in Figure 7. In principle it is related to the technique of specimens from Canyon de Chelly (fig. 6) and from Bear Creek on Blue River (fig. 17). I have grouped these variants as all of one sifter-coiling type, called type B.

PALATKI, CENTRAL ARIZONA

Basketry fragments found in a cliff house by J. W. Fewkes are in the United States National Museum. I have seen a fragment of coiling and a number of fragments of twining.

Coiling.—The coiled fragment is made with noninterlocking stitches, on a three-rod-triangular foundation (fig. 11). It is rather coarse work, running 6 coils and 9 stitches to the inch.

Twining.[7]—These fragments are parts of what were evidently large conical burden baskets, made in twilled-twining (fig. 14). The stitch

[1] U.P.M., both specimens without number.

[2] U.P.M., Wetherill No. 11 D (found with human remains).

[3] The bowls and tray are U.P.M., no number; the cylindrical fragment is U.P.M., Wetherill No. B 36.

[4] U.C.M. No. 2/3072.

[5] The two trays are U.P.M., no number.

[6] The two pieces are U.P.M., no number.

[7] U.S.N.M. No. 156293; Basket fragments, Palatki, Ariz., ruin A, house G (J. W. Fewkes, 634).

is regular twilled-twine to the rim, three-strand twine (fig. 15) at the rim and the rim finish consists of two rows of loose coiling, with noninterlocking stitches on a scrap foundation. The twine stitches trend upward toward the right. No decoration is discernible. It seems likely that in shape and technique these baskets were similar to modern Havasupai burden baskets.

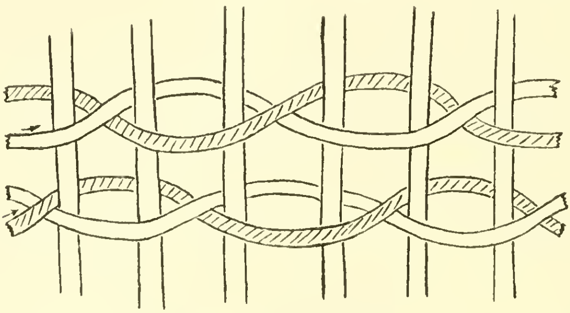


FIG. 14.—Twilled-twining.

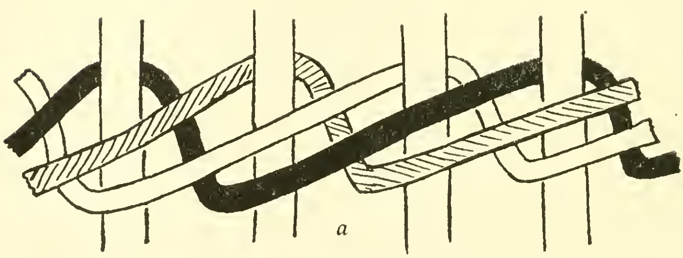


FIG. 15.—Three-strand twining.

LITTLE COLORADO RIVER REGION, ARIZONA

CHAVES PASS

In the United States National Museum are fragments of coiled basketry secured by Fewkes at this location.[1] They show evidence of having been painted with red and blue paint. The stitches are noninterlocking; the foundation is three-rod-triangular (fig. 11), composed of very fine thin rods. The fragments are so badly battered as to make any further comment hypothetical.

[1] U.S.N.M. No. 157925.

Chevlon Ruin[1]

Fewkes collected from this site 12 fragments and a large part of a broken basket, all in coiling. I examined the broken basket in the United States National Museum.[2]

The coiling is made on a three-rod-triangular foundation (fig. 11), counterclockwise spiral, concave work surface, toward the left of the worker (fig. 1*a*), with noninterlocking stitches (fig. 11). The foundation rods are very thin and fine. The basket is all in black with a fret pattern in natural thread: reconstructed, it is a shallow

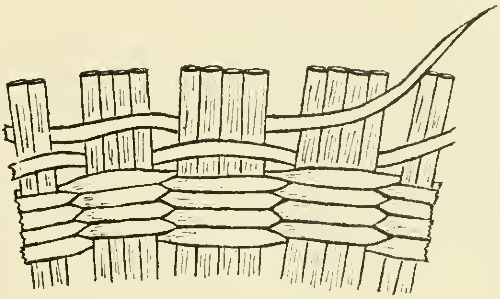


Fig. 16.—Wickerwork.

basket with flat bottom and vertical walls, diameter of bottom, 3½ inches, height of walls about 1¾ inches.

The specimens from this site are technically similar to those from Chaves Pass.

A specimen of wickerwork in every respect like modern Hopi wickerwork of Third Mesa was recovered by Fewkes from Chevlon Ruin (fig. 16).[3]

LOWER GILA REGION

Casa Grande

From Casa Grande there are a large number of charred fragments of coiled basketry in the United States National Museum. In the Museum is also one coiled tray from this site, with a black meander design in martynia thread, which is unquestionably of Pima manufac-

[1] Chevlon Ruin is 15 miles from Winslow.

[2] U.S.N.M. No. 157915; see also J. W. Fewkes, 22nd Ann. Rep. Bur. Amer. Ethnol., pt. 1, p. 99 and fig. 63. The same basket is figured in Mason, pl. 220, and p. 509.

[3] Mason, pl. 219 and p. 508.

ture in all respects, differing decidedly from the other material from the site.[1]

The coiling of the charred fragments is made on a three-rod-triangular foundation (the foundation rods are very fine and thin), with noninterlocking stitches (fig. 11) and plain edge. It looks as though the edge might have been sewn with martynia thread. Measurements: 6 to 8 coils and 14 stitches per inch. Technically this work is similar to the coiling of Chevlon Ruin and Chaves Pass, as above.

UPPER GILA REGION

Bear Creek on Blue River

From this site (Montezuma's cave) Hough obtained a large number of baskets.[2] There are baskets in close coiling, sifter coiling, and twill-plaiting, and one specimen in an unusual technique—wrapped coiling. Hough also mentions wicker baskets which I have not seen.

Close coiling.—Six specimens I examined included two bowls about 5 inches in diameter and 2 inches in height, one fragment of the neck of a globular basket, one fragmentary bowl rim, and two miniature globular baskets ($2\frac{1}{4}$ inches in diameter, $1\frac{1}{2}$ inches in height; $1\frac{1}{4}$ inches in diameter, 1 inch in height).[3] In all these specimens, the coiling stitches are noninterlocking and are made on a two-rod-and-bundle-triangular foundation (fig. 2). The bowls and fragments were worked on the concave work surface toward the left of the worker (fig. 1*a*); the two miniature globular baskets were worked on the convex surface (inevitable in such globular forms) to the right of the worker—an anomalous direction of work, which is probably to be explained by attributing them to left-handed basket making. The texture of the stitching in the fragments and in the miniatures is very fine, that in the two small bowls, a little coarser; the range of the measurements is from 7 coils, 23 stitches per inch in one fragment to 4 coils, 10 stitches per inch in the coarser bowl. Decoration: one bowl is decorated in red and black, the other in black, and the larger miniature globular basket has a dark red decoration.

Sifter coiling.—Twelve small, possibly miniature, sifter baskets[4] (the range of diameters is from 2 inches to $5\frac{1}{4}$ inches) are consistent

[1] U.S.N.M. cat. 254596, acc. 49619, o. 296, Fewkes, prehistoric Casa Grande.

[2] Hough, 1907, pp. 50-52 and 24-25.

[3] U.S.N.M. Nos. 246130; 246128; 232103; 246156 (cf. Hough, 1914, pl. 17, No. 4); 246129 and 232096 (cf. Hough, 1914, pl. 17, Nos. 2 and 5).

[4] U.S.N.M. Nos. 246142, 246143, 232089, 246140, 246139, 246134, 246136, 246141, 246137, 232087, 246131; 246135 (cf. Hough, 1914, pl. 24); 246138 (this

in all technical aspects except foundation. They are worked on the concave work surface to the left of the worker (counterclockwise spiral) with noninterlocking stitches. The stitch technique is what I have called type B sifter coiling, which includes also specimens from Canyon de Chelly (fig. 6) and from the Hazzard collection (fig. 7). Foundations are of three types: three baskets are on two-rod-and-bundle-triangular (fig. 2) ; six are on multiple grass (fig. 17) ; and three are on rod-surrounded-by-bundle (fig. 3). The thread is wrapped about the course of coiling in work and at intervals is fastened to the course below. There are two ways of treating the fastening stitch: either the stitch is caught in the foundation of the course below the one in work (fig. 17) (analogous to Canyon de Chelly specimen), or the stitch passes underneath the lower course (analogous to

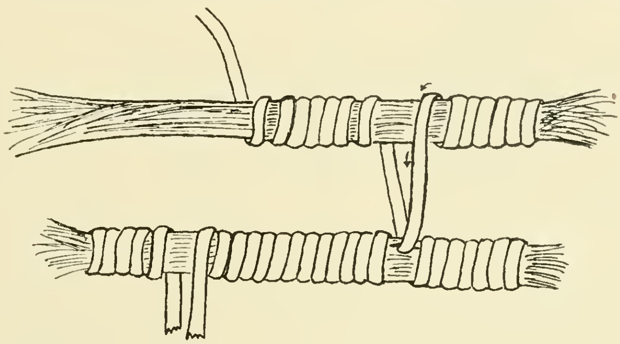


FIG. 17.—Sifter coiling on a multiple-grass foundation. (Type found at Bear Creek on Blue River; variant of type B.)

the Hazzard collection specimen). This latter method of fastening the stitch occurs in the three specimens with rod-surrounded-by-bundle foundation; in the remaining nine with two-rod-and-bundle-triangular and with multiple-grass foundations, the stitch is caught in the foundation of the lower course. This variety of type B sifter coiling differs from the other two kinds in that the fastening stitch is not bound around itself between the courses. It differs further from the Canyon de Chelly variety in that instead of the fastening stitches being made one directly above the other, they are fastened in alternate order in the successive courses (see p. 11 and fig. 7).

In all the baskets the starting knot is so made as to leave a large hole in the center bottom; all are finished off with a few false-braid

specimen is fastened with thread to a small stick, umbrella-fashion; cf. Hough, 1914, fig. 317). Hough, 1907, p. 25, refers to these sifter baskets as "lazy stitch."

stitches. All the baskets are decorated on the outside, the non-work surface, by painting in colors: black, red and black, red, black and white, red and blue. Two, in addition, are painted all over inside with red. (These two have respectively, outside decoration in red and black, and red and blue, and are both on a multiple-grass foundation.)

Wrapped coiling.—One small conical basket is made in wrapped coiling similar to the work of Mohave burden baskets; the weaving strands are of basket-thread.[1]

Twill-plaiting.—Three specimens of twill-plaiting[2] in over-3-under-3 weave; the first is a yucca-ring basket with concentric diamond pattern (fig. 4), the second is a finely woven yucca-ring basket with

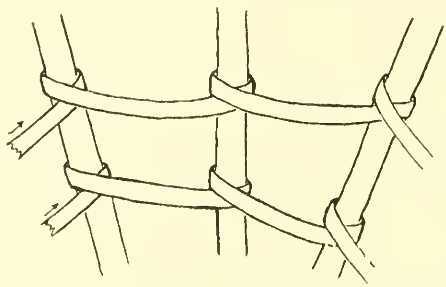


FIG. 18.—Wrapped coiling.

a square rim ring and diagonal design,[3] and the third is an olla-shaped basket with a bottom design of a cross into which are set four series of concentric right-angled elements. This olla shape was made all in one piece, evidently beginning at the center bottom.[4]

A twill-plaited specimen of special interest is a small, flat square mat with key pattern.[5] (Compare with Nordenskiold's plaited baskets from Mesa Verde, described above.)

RIO GRANDE REGION

PAJARITO PLATEAU, N. MEX.

From the small-house ruins of the Pajarito Plateau there is evidence of a great deal of close coiling and some twill-plaiting which may be mat work. The evidence is in the form of " an extraordinarily high

[1] Hough, 1907, p. 25, refers to this Mohave type work; see also Mason, p. 230, fig. 13, and Hough, 1914, p. 88 and fig. 318.

[2] U.S.N.M. Nos. 246159; 246161; 246160.

[3] Hough, 1914, pl. 17, No. 1.

[4] Hough, 1914, pl. 17, No. 3; also fig. 179.

[5] Hough, 1914, pl. 16, No. 2.

percentage of basket-marked sherds " found in association, primarily, with black-on-white pottery.[1]

Kidder observes: " Such sherds occur, it is true, in most other black-and-white groups, but they are of the greatest rarity. Here, however, they can be picked up at almost any site. The impressions show that bowls and the lower parts of ollas were often formed in baskets. In these cases the clay was apparently coated on the inside of the basket and pressed down hard enough to render the marks of the weave sharp and clear. The upper parts of ollas were probably constructed by the regular coiling method. Some bowls, however, seem to have been molded or cast entire in basket forms, as the impression of the weave runs to the rim. The baskets themselves were all of the coiled variety, tray- or bowl-shaped; the coils measure 4 to 5 mm in breadth and there are about six stitches to the centimeter " (15 plus stitches, 5 to 6 coils per inch).

From the photographed basketry-marked sherd, with the accompanying cast,[2] the coiling is close work, either on a two-rod-and-bundle-triangular foundation (fig. 2), or on a three-rod-triangular foundation. More probably it is the former. If it were made on a three-rod-triangular foundation (fig. 11), the appearance would probably be more rugose and the depressions between the courses of coiling, deeper. The sherd betrays suggestions of a zigzag design which was made in a heavier thread than the regular sewing thread, as shown by zigzag rows of deeper impressions in the sherd, higher elevations in the cast.

In my opinion the general texture and finish of the basketry suggested by this sherd is decidedly similar to Basket Maker type work of the finer (Cliff Dweller) grade.

Lower Rio Grande Region

Three sites in the Lower Rio Grande Region have yielded specimens of prehistoric basketry.

SITE NEAR LAS CRUCES, N. MEX.

From a site near Las Cruces, N. Mex., there are four baskets in the United States National Museum. Some basketry sherds were also found, but no pottery.[3]

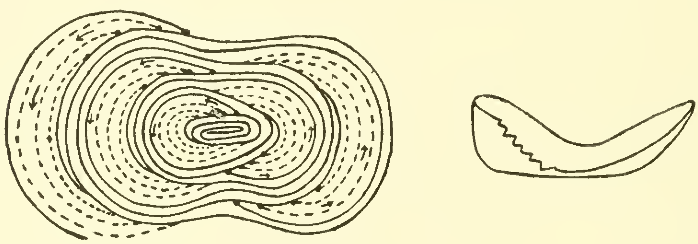
[1] Kidder, 1915, pp. 413-414, and pl. 14. Pl. 14*b* shows on the filling-in of the mouth of a broken olla the impression of a twill-plaited mat; see also Kidder's text, p. 426.

[2] Kidder, 1915, pl. 14*a*. From the standpoint of the way the basket was made, the sherd should be examined with the page inverted.

[3] I examined these four specimens in the United States National Museum through the courtesy of Dr. Walter Hough. They were obtained in connection

All four specimens are in close coiling. Two are rather deep, round bowls, one a burden basket of an unusual shape—in profile the basket shows deeply concaved walls and widely flaring mouth; a cross-section would be ovaloid—and the fourth is a unique specimen of coiling in that it is shovel-shaped (fig. 19*b*). While it is probable that the burden basket had a design, in their present condition no designs could be made out on the first three of the above. In the shovel-shaped basket a radial design appears, sewn in dark red bark (almost a black).

In all technical traits, the four baskets are Basket Maker type, consistently on two-rod-and-bundle foundation (fig. 2); the stitch texture is coarse. The first three specimens are sewn with wood sewing thread, the usual Basket Maker type sewing thread, while in the shovel-shaped basket, a yucca sewing thread was used.



a *b*

FIG. 19.—Shovel-shaped coiled basket from site near Las Cruces, N. Mex. *a*. Shows the insertion of several sets of partial circuits to produce a form narrow in the middle, with walls built up at the two ends. *b*. Profile view.

The shovel-shaped basket, being an unusual shape for coiling, shows a special way of using the coiling technique. In addition to the usual continuous circuit, partial circuits of coiling are introduced at intervals as illustrated (fig. 19).

WEST OF SACRAMENTO MOUNTAINS

From a cave on the west side of the Sacramento Mountains I have seen a fragment of coiled basketry.[1] This is in the typical Basket Maker technique of coiling on a two-rod-and-bundle-triangular foundation with noninterlocking stitches. The texture runs 5 coils, 10 stitches per inch. The fragment is too small to determine work surface or possible shape.

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with the Yale Expedition of 1929. The site is further identified as Dona Ana County, in the southwestern portion of New Mexico, close to the east bank of the Rio Grande, about 25 miles north of the Texas State line. The shovel-shaped basket is U.S.N.M. No. 345916.

[1] Found by E. B. Howard of the University Museum, Philadelphia.

WEST OF CARLSBAD, N. MEX.

From a cave 50 miles west of Carlsbad, I have seen a coiled fragment which is in Basket Maker technique.[1] The texture is coarser than the Sacramento specimen, running 4 coils, 8 stitches per inch. The foundation was probably rod-surrounded-by-bundle-of-fiber. The arrangement of splicings suggests that the surface may have been originally in two colors, with a design in triangular elements.

The indications are that the Lower Rio Grande region forms the southeastern boundary of the Southwestern basketry area. Further to the south a distinct type of coiled basketry is found. I have so far seen material of this Texas type from Brewster County, Texas,[2] from D. G. Knight cave (20 miles southwest of Valentine, Texas),[3] and from the Guadalupe Mountains.[1]

The Texas type of coiled basketry is made on a bundle-of-grass foundation, with stitches split on the non-work surface, worked toward the left of the worker, on the concave surface; yucca sewing thread is used.

ANCIENT PUEBLO

Over a period of many years, basketry has been secured from a number of the existing pueblos (as well as one ruin—Sikyatki) which have been classified as "ancient pueblo." There is no adequate evidence as to who made these baskets, but there can be little doubt that they are of considerable antiquity.

Many of the baskets were collected long ago by Stevenson and Powell and are illustrated by photographs in Mason.[4] There are occasional specimens in other museums, some obtained quite recently, and still others are today in the hands of traders in Santa Fe and elsewhere.

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[1] Found by E. B. Howard of the University Museum, Philadelphia.

[2] Found by M. R. Harrington of the Southwest Museum. Specimens now in Museum of the American Indian, Heye Foundation.

[3] Found by F. M. Setzler of the U. S. National Museum.

[4] I give below in reference to the specimens, Mason's plates and page references; there is some confusion in the Mason references; where my museum number references do not agree with his information, they should be taken as a correction of Mason, as they have been obtained directly from the specimens. This is also true of some of Mason's allocations to pueblos and collectors.

Sikyatki

Culture horizon: Late Pueblo IVa.

In the United States National Museum there are specimens of basketry from Sikyatki in three techniques: wicker, close coiling, and twill-plaiting.[1]

From the illustrations, the coiling is made on a bundle foundation and sewn with yucca sewing thread. This identifies it with modern Hopi coiling now made on Second Mesa.

The technique of the wicker specimen is also identical with the modern Hopi wickerwork now made on their mesa (fig. 16).

The twill-plaiting seems to be in too bad a condition to make out details from the photograph. The piece may have been part of a yucca-ring basket, such as are made today on Second Mesa; or it may be a piece of matting. In either case it seems similar to modern Hopi work.

Hopi (Moki)

From Hopi, I have seen four coiled baskets, three of which are bottle shapes, and one an oblong oval basket (boat-shaped):

U.S.N.M. No. 68473 (Mokis, J. W. Powell), not illustrated in Mason. Measurements: total height 9⅝ inches; diameters, bottom 8½ inches, neck 5¼ inches, mouth 7¼ inches; 4½ coils, 14 stitches per inch. Design in black and red.

U.S.N.M. No. 68474 (Mokis, J. W. Powell), Mason, pl. 214, third basket from left in upper row; also Mason, p. 502. Measurements: total height 7 inches: diameters, bottom 7½ inches, neck 4¾ inches, mouth 5¾ inches, 4 coils, 12 stitches per inch. Design in red and black.

A.M.N.H. No. 50/9579 (Hopi); in shape, size, and texture similar to the above. No design discernible.

U.S.N.M. No. 68471 (Mokis, J. W. Powell), Mason, pl. 214, first basket at left in upper row; and Mason, p. 502.[2] Measurements: 3¾ inches high: diameters, bottom 9¼ inches, mouth 7½ inches; 5½ coils, 13 stitches per inch. No design discernible.

All the above specimens are in Basket Maker type coiling; two-rod-and-bundle-triangular foundation (fig. 2), noninterlocking stitches, convex work surface, clockwise spiral, worked to the left of the worker (fig. 1*b*). The American Museum specimen is made on the concave surface past the bend (fig. 1*a*), then work is transferred to the convex surface and proceeds thereafter from the outside (fig. 1*b*).[3]

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[1] Mason, p. 509 and pls. *221*, *222*.

[2] Mason, p. 502, calls these two baskets Stevenson's Zuñi collections; this disagrees with catalogue and specimens. Note that the photograph of U.S.N.M. No. 68471 shows in white the designation as I have it.

[3] See also in reference to this change of work surface, Amer. Anthrop. vol. 32, p. 486. The presence of both of these methods, viz., globular baskets worked

In addition to the above specimens, Mason, Plate 218, pictures nine "ancient baskets from Oraibi," of which seven are coiled and two twined.[1] Six of the coiled baskets are on three-rod-triangular foundation (fig. 11). In texture and technique these coiled baskets are different from those above described, resembling the modern work of Utes. The large twined water bottle has a frame woven in like that of a burden basket, as has also one of the twined bottles from Zuñi (Mason, pl. 213, upper center).

Santa Ana

In the Museum of the American Indian, Heye Foundation, there is a coiled, bottle-shaped basket collected in Santa Ana.[2] The measurements are: 7½ inches high; diameters, bottom 8½ inches, mouth 7 inches; 5½ coils, 14 stitches to the inch. The technique is in every particular Basket Maker type coiling on two-rod-and-bundle-triangular foundation (fig. 2). There is a design in red and black.

Sia

From the pueblo of Sia there are six coiled bottle-shaped baskets:

U.S.N.M. No. 134213 (Siana, N. Mex., Stevenson), Mason, pl. 28, lower, and p. 253.[3] Measurements: total height 9¼ inches; diameters, bottom 9½ inches, neck, 5⅛ inches, mouth 7½ inches; 4 plus coils, 15 stitches per inch. Design in black.

U.S.N.M. No. 134214 (Stevenson; Mason, p. 499, calls this Sia), Mason, pl. 212, lower. Measurements: height 9 inches; diameters, bottom 8 inches, neck 6 inches, mouth 7 inches; 4 coils, 12 stitches per inch. Design in red and black.

U.S.N.M. No. 134214 (Siana, N. Mex., Stevenson), Mason, pl. 214, lower row, fourth from the left, and Mason, p. 502.[4] Measurements: 11¼ inches high; diameters, bottom, 7¾ inches, neck, 4⅝ inches, mouth 6½ inches; 5 coils, 12 stitches to the inch. Design in red and black.[5]

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throughout on the convex surface, and others with change of work surface is not inconsistent with finds of typical Basket Maker material, viz., Marsh Pass collections of Kidder and Guernsey.

[1] Mason, pp. 506-507, describes these baskets, pointing out that one is modern; he lists museum numbers.

[2] M.A.I., H.F. No. 7/825.

[3] Mason, p. 253, calls both baskets in pl. 28, Sia, while he titles pl. 28 itself, Zuñi. The upper basket is Zuñi, the lower is Sia.

[4] Note that this basket and the preceding one have the same museum numbers as well as the two specimens numbered 134215. There are four specimens, not two.

[5] That the design of this and the preceding specimen is red and black is my judgment; at the present day both designs appear as faded brown and red.

U.S.N.M. No. 134215 (probably Gill, 1902?), Mason, pl. 212 upper and p. 499f. Measurements: height $7\frac{1}{4}$ inches, diameters, bottom 6 inches, neck $4\frac{3}{8}$ inches, mouth $5\frac{1}{4}$ inches; 5 coils, 13 stitches per inch. Design in black.

U.S.N.M. No. 134215, Mason, pl. 214, lower row, third from the left. I have not seen the specimen. Mason gives, p. 502, diameter $11\frac{1}{2}$ inches. Design not discernible from photograph.

Eldody collection, No. 8463 (seen in La Fonda shop, Sante Fe, N. Mex.). With a rawhide band and handle around the neck; design in red and black.

All the above specimens are made in every particular in Basket Maker type coiling on a two-rod-and-bundle-triangular foundation (fig. 2), convex work surface (fig. 1*b*).

Zuñi

From Zuñi there are three coiled bottle shapes and two coiled globular baskets.[1]

U.S.N.M. No. 68550 (Zuñi, Powell), Mason, pl. 214, second basket from the left in the upper row, and p. 502. The basket has a small leather handle; design in black. Measurements: total height $4\frac{1}{2}$ inches; diameters, bottom 4 inches, mouth $3\frac{3}{4}$ inches; 5 coils, 13 stitches per inch.

U.S.N.M. No. 42140, Mason, pl. 214, first basket from right in upper row, and p. 502. Measurements: $4\frac{1}{4}$ inches high; diameters, bottom 4 inches, neck $3\frac{1}{4}$ inches, mouth $4\frac{5}{8}$ inches; 5 coils, 10 stitches per inch. Leather handle; design in black.

U.S.N.M. No. 68489 (Zuñi, Stevenson), Mason, pl. 214, lower row, second from the left,[2] and p. 502. Measurements: total height $9\frac{3}{4}$ inches; diameters, bottom $8\frac{1}{2}$ inches, neck $4\frac{1}{4}$ inches, mouth $6\frac{1}{8}$ inches; $3\frac{1}{2}$ coils, 10 stitches per inch. Design in dark red.

U.S.N.M. No. 68472 (Zuñi, Powell), Mason, pl. 214, upper row, fourth from left and p. 502. Measurements: $4\frac{3}{4}$ inches high; diameters, bottom $5\frac{1}{2}$ inches, mouth, $5\frac{3}{4}$ inches; $3\frac{1}{2}$ coils, 11 stitches per inch. Leather handle; design not discernible.

U.S.N.M. No. 68479 (Zuñi, Powell), Mason, pl. 28 upper and p. 253. Measurements: $5\frac{1}{4}$ inches high; diameters, bottom $7\frac{3}{4}$ inches, mouth $9\frac{1}{2}$ inches; 5 coils, 15 stitches per inch. Design in red and black.

The above five specimens are in every particular Basket Maker type coiling on a two-rod-and-bundle-triangular foundation (fig. 2) and convex work surface throughout (fig. 1*b*). The last one has the bottom broken out and a false bottom sewn in which is coarse coiling on a three-rod-triangular foundation, with stitches split on the non-work surface which faces the outside bottom.

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[1] There is also U.S.N.M. No. 68546 (Zuñi, Powell), Mason, fig. 189, p. 503. I have not seen this specimen. From Mason's figure it seems very likely to be a Chiricahua Apache basket; it is not at all similar to the baskets above.

[2] Mason, p. 502, has apparently transposed the numbers of the first and second baskets from the left in the lower row of his pl. 214.

Besides these coiled baskets called "ancient Zuñi," Mason also figures (pl. 213) seven twined baskets and one wicker basket, collected by James Stevenson. The twined baskets are bottle-shaped, while the wicker basket is globular. The types of twined stitches used include plain twining, twilled twining (fig. 14), and three-strand twining (fig. 15).[1] The twining is made toward the right of the worker (clockwise spiral, convex work surface) stitches trending upward toward the right in the direction in which the work proceeds. The technique of the wicker basket is similar to modern Hopi work, Third Mesa (fig. 16).

Miscellaneous

Besides the above baskets, there are seven coiled baskets secured in pueblos, and classified as "ancient pueblo" which do not specify what pueblo. All are bottle shapes.

U.S.N.M. No. 313165 (collected by Hubby[2]). Design in red and black.[3]

U.S.N.M. 328022 (Hubby[2]). Design in red and black.[3] Measurements: $7\frac{3}{4}$ inches high; diameter 10 inches; 4 coils, 15 stitches per inch.

U.S.N.M., no number. Measurements: 4 inches high, diameters, bottom $4\frac{3}{4}$ inches, mouth $3\frac{5}{8}$ inches; 4 coils, 11 stitches per inch. Probably undecorated.

U.S.N.M. No. 221415 (collected by F. H. Cushing). Measurements: $11\frac{3}{4}$ inches high; diameters, bottom $8\frac{1}{2}$ inches, neck $5\frac{1}{8}$ inches, mouth 6 inches; 4 plus coils, 13 stitches per inch. Design in faded dark brown or black.

U.S.N.M. No. 166800 (Mooney, Apache).[4] Measurements: 5 inches high; diameters, bottom $4\frac{1}{2}$ inches, mouth $3\frac{1}{2}$ inches; 5 coils, 12 stitches per inch. Design not discernible.

Indian Arts Fund, Santa Fe (no number). Measurements: 8 inches high; diameters, bottom 8 inches, mouth $5\frac{3}{4}$ inches; 4 coils, 14 stitches per inch. Design in black.[3] Buckskin handle around neck.

F.M.N.H. No. 103032 (obtained at Navajo, Ariz., by H. E. Sargent). Measurements: $9\frac{3}{4}$ inches high; diameters, bottom and mouth $7\frac{1}{4}$ inches; 5 coils, 13 stitches per inch. Design in red and black. Two rawhide lugs on shoulder.

The seven baskets are in every particular Basket Maker type coiling on a two-rod-and-bundle-triangular foundation (fig. 2); all are made on the convex work surface throughout (fig. 1*b*).

[1] Mason, pp. 500-501, describes the specimens and gives museum numbers.

[2] Mrs. Hubby calls these Paiute ceremonial baskets. "These baskets were used by and are found among the Pueblo Indians. They were used to buy a fetich." These two baskets are in no technical or decorative aspects similar to Paiute work.

[3] The designs on these three baskets resemble in style those on the "Ancient Pueblo" baskets from Sia.

[4] From the note "collected among the Apaches by Mooney"; but not like Apache work. Consistent with the "ancient pueblo" baskets of this type.

TYPES OF BASKETRY

In the preceding notes, it will be seen that certain technical types stand out clearly:

In coiling there are the three types with triangular foundation elements: Basket Maker, in two varieties: two-rod-and-bundle-triangular (fig. 2) and two-rod-and-reed-triangular; Cliff Dweller; and the type with three-rod-triangular foundation (fig. 11). All three are consistent in left direction of work, concave work surface (figs. 1*a*, *b*), noninterlocking stitches (fig. 2). The difference between the Basket Maker and Cliff Dweller is one of texture. Both have two-rod-and-bundle-triangular foundation (fig. 2). The third type differs from the two preceding only in that the foundation is three-rod-triangular instead of two-rod-and-bundle. There is also the type on single-rod-surrounded-by-fiber-foundation, with noninterlocking stitches (fig. 3).

One other coiling technique occurs with sufficient frequency to be called a type. This is the coiling on one-rod foundation with interlocking stitches (fig. 5), left direction of work and concave work surface (fig. 1*a*).

In sifter coiling, there are two types, A (fig. 8) and B (figs. 6, 7, 17), of which the latter occurs with minor variations.

In twill-plaiting there are two types, the yucca-ring baskets made from center bottom upwards (fig. 4), and the second type which is probably made from mouth down with the bottom unfinished.

Basket Maker Type Coiling

On the basis of the textual distinction between Basket Maker and Cliff Dweller material, basketry of Basket Maker type coiling occurs in the preceding enumeration in Marsh Pass and associated sites, Canyon del Muerto, Canyon de Chelly, the Piedra District, Grand Gulch, Kane County, Battle Canyon, Allan Canyon, Lake Canyon, among the Wetherill material from southern Utah and southwestern Colorado, possibly at Las Cruces, N. Mex., and in caves of the Lower Rio Grande Region.

The Basket Maker subvariety, distinguished from the regular Basket Maker only in that the foundation is two-rod-and-reed-triangular, occurs in Canyon del Muerto, Battle Canyon, Navaho Canyon, Lake Canyon, and in the Wetherill material from southern Utah and southwestern Colorado.

Cliff Dweller Type Coiling

Material of such fine texture as to be associated typologically with Cliff Dweller material rather than Basket Maker material, is found at Marsh Pass, Betatakin, Cradle House, other Navaho National Monument sites, Mesa Verde, Johnson Canyon, Canyon del Muerto, White Canyon, Allan Canyon, Butler Canyon, Pueblo Bonito, among the San Diego material from southern Utah, among the Wetherill pieces from southwestern Colorado (and southern Utah), Bear Creek on Blue River, Pajarito Plateau, and " Ancient Pueblo " material.

The above distinctions, being typological, are, of course, tentative and subject to correction; where but few specimens are recovered, no range of measurements can be taken and certain measurements are bound to fall in an intermediate class, as, for example, those of the " Ancient Pueblo " material. Also, in view of the close association of Cliff Dweller and Basket Maker cultures as indicated by Kidder and Guernsey, and the probability that Cliff Dweller peoples looted Basket Maker remains, where we have only miscellaneous specimens from a location it is likely that we are dealing with a mixture of the types.

Three-Rod-Triangular Type Coiling (fig. 11)

Material consistent with Basket Maker type coiling except for three-rod-triangular foundation comes from Navaho Canyon and Cliff Palace (Mesa Verde), Pueblo Bonito, Palatki, Chaves Pass, Chevlon Ruin, and Casa Grande; one such basket also is in the Wetherill collection.

In connection with the above three types, it is important to note that all have triangular-form foundations. Triangular-form foundation in North American coiled basketry, modern as well as ancient, has a definitely limited distribution. In prehistoric material it occurs in Lovelock Cave as well as in the Southwest. In modern material it occurs among the Pomo-Maidu-Miwok, Paviotso and Southern Paiute, Chemehuevi, Ute, Havasupai, San Carlos and Jicarilla Apache, and Navaho. Its northernmost occurrence is among the Pomo and its southernmost among the San Carlos Apache. It is likely that three-rod-triangular foundation is a later development from two-rod-and-bundle, and that two-rod-and-reed-triangular foundation is a transitional step. To the basket maker, the function of the apex element is to bind the courses together. The sewing thread passes through the apex bundle (fig. 2), reed or rod (fig. 11). On the other hand, there is no mechanical reason for placing the lower two elements side by side, save perhaps to thicken the walls; but this could be accomplished in other ways. Thus the origin of the use of triangular foundations in basketry coiling can not be determined by functional factors, but must rather be credited to historical factors. With this in mind, and considering the limited area of distribution for triangular-form foundations, there is some reason to believe that ultimately these contiguous appearances of the use of such a foundation are in some way historically related.

In some of the Basket Maker material there are occasional baskets, as noted, which have a foundation of rod-surrounded-by-fiber (fig. 3); namely, close-coiled baskets from Marsh Pass, Kane County, Allan Canyon and the Lower Rio Grande Region, and sifter coiling from Bear Creek and in the Wetherill collection. The close-coiled baskets are in other traits like the Basket Maker—Cliff Dweller complex. From a formal standpoint, this type of foundation can be classified with bundle foundation (fig. 17). Little of historical significance can be drawn from similarities in basket-making technique which are based merely on the use of bundle-form foundations, since this is the most universally used type of foundation in coiled basketry in the world. Mechanically, it is the most elementary. The function of the bundle is to give a foundation body through which the sewing stitch can readily pass, binding course to course.

One-Rod-Foundation Coiling

From Canyon de Chelly, Grand Gulch, Battle Canyon, Allan Canyon, and in the San Diego collection from southern Utah and the Wetherill collections, there are coiled baskets on a one-rod foundation with interlocking stitches (fig. 5), counterclockwise spiral, concave work surface toward the left of the worker. It seems likely that these will prove to have been intrusive ware. In addition, there are two specimens of one-rod coiling, as above, save that the stitches do not interlock (fig. 12). One of these is a complete basket from Lost Canyon: the other is a Wetherill basket from Navaho Canyon, the walls of which are in one-rod coiling, the rim in two-rod-and-reed-triangular coiling. It is interesting to note that on a basket which, from its other traits is Basket Maker type coiling, the one-rod coiled stitches do not interlock. The stitching of the Lost Canyon basket is unusual in that it has a wrapping of the new foundation rod alternating with each regular stitch.

Unusual Coiled Specimens

In the Wetherill material from southern Utah and southwestern Colorado are two trays on a two-rod-and-reed-triangular foundation, apparently of the usual Basket Maker type and texture, but with interlocking stitches. These are the only examples of coiling other than on a one-rod foundation with interlocking stitches.

Two coiled bowls from Battle Canyon which are Basket Maker type coiling in all other respects are made on a foundation of half a heavy rod with a strip of yucca placed upon it, through which the stitches are caught (fig. 9).

Two baskets are unusual in that they have foundations of vertical form. One is the oblong basket from Battle Canyon which has a three-rod-vertical foundation (fig. 10), although the rim coil is made on a foundation of two rods placed side by side; the other is a basket from Sandal Cliff House, Mancos Canyon, made in double coiling on a two-rod-and-bundle vertical foundation (fig. 13).

Sifter Coiling

This technique occurs in two types which I have called A and B. Type A (fig. 8) is found without variation in a specimen from Grand Gulch, one from Kane County, and one from Lake Canyon. Type B occurs in three variants. The Hazzard collection specimen is from the Wetherill material, and comes from southern Utah or southwestern Colorado (fig. 7). A simpler type, without binding stitch around the "standing-part," is found in 12 specimens from Bear Creek on Blue River (fig. 17). A type with double binding around the "standing-part" is found in the Canyon de Chelly material (fig. 6); the specimen differs from the Hazzard collection specimen in that instead of the bindings alternating in the successive rows, they are found one above the other, forming vertical lines which radiate from the center. The Blue River specimens show both these methods of placing the fastening stitch. On a basket-marked sherd from Canyon del Muerto there is evidence of sifter coiling which resembles the basket from Canyon de Chelly. As sifter coiling is a unique technique in North America, unknown in modern work save for the "grasshopper" baskets of the Yokuts,[1] and as the two types mentioned are not mechanically related, these two distributions are of importance historically.[2]

In foundation, type A is consistently made on a single-rod. Type B occurs with three foundations: two-rod-and-bundle-triangular (fig. 2), rod-surrounded-by-fiber (fig. 3), and bundle-of-grass (fig. 17). Thus type B, on the basis of foundations, is to be associated with Basket Maker close coiling, while type A affiliates rather with the one-rod coiling with interlocking stitches which occurs sporadically (figs. 5, 8).

[1] Mason, pl. 196; p. 480, figs. 172 and 173.

[2] I have seen modern basketry in shops made in type B sifter coiling said to have been made by Mexican natives.

Twill-Plaiting

Yucca-ring baskets (fig. 4) and twill-plaited baskets of that type are found in Marsh Pass Cliff Dweller material, and occur also at Betatakin, Canyon del Muerto, Canyon de Chelly, Grand Gulch, Butler Canyon, Navaho Canyon, Spruce Tree House, Red Canyon, Colorado River Canyon, Pueblo Bonito, in the southern Utah material of the San Diego Museum, and at Bear Creek on Blue River. Kidder and Guernsey established this type of basket at Marsh Pass as the typical Cliff Dweller product, and there seems reason to believe that the specimens from other localities are to be associated with the same culture horizon.

Twill-plaited baskets with unfinished bottom were found at Marsh Pass (with Basket Maker material), Canyon del Muerto, Canyon de Chelly, Grand Gulch, and southern Utah (S.D.M.). The Basket Maker associations of the Marsh Pass material suggest that this unfinished bottom type is earlier than the Cliff Dweller yucca-ring type.

From Johnson Canyon, Aztec Ruin, and Sikyatki there is evidence of twill-plaiting which may be baskets, but if so the type can not be determined.

Wickerwork

Wickerwork has been mentioned in the above treatment as found in Chevlon Ruin (fig. 16) and at Bear Creek on Blue River, in Sikyatki and in the Zuñi "Ancient Pueblo" collection. This wicker technique is the same as modern Hopi and Zuñi wickerwork. Prehistorically, wickerwork is found in Lovelock,[1] and in modern work in Pomo seedbeaters and Algonquian trinket baskets.

Twined Basketry

Twined basketry is unknown in Basket Maker material. In the above enumeration, twined basketry is referred to from Palatki (figs. 14, 15) and in the "Ancient Pueblo" material of Hopi and Zuñi. In shapes, technique, and texture this work resembles modern work of Havasupai and Hualapai, and of modern Ute. Except for the evidence of shapes, this twined work could also be compared with that of Apache groups.

[1] Cf. Amer. Anthrop., vol. 32, pp. 490-491. The statement that wickerwork in prehistoric material is "found exclusively" in Lovelock Cave is to be considered corrected by the statement in this paper.

Baskets Showing Combinations of Techniques

In the foregoing discussion several coexistences of two techniques on the same specimens occur:

The basket from Navaho Canyon (Mesa Verde) which has walls on a single-rod foundation with a rim made on two-rod-and-reed-triangular foundation indicates the contemporaneity of single-rod foundation coiling and Basket Maker coiling; but it should be noted that the one-rod coiling here is without interlocking stitches (fig. 12). Single-rod foundation coiling with noninterlocking stitches is unusual, and its distribution sporadic in modern times. In prehistoric material the specimen in question is the only one known to me which is normal single-rod coiling; the specimen from Lost Canyon has special peculiarities. In modern work one-rod noninterlocking coiling is limited to a few coiled baskets of the Paviotso Paiute. In the Paviotso work, the absence of interlocking is not a conventional trait of their technique, as in collections of their one-rod coiled baskets interlocking and split stitching are to be found as well as noninterlocking. By contrast, one-rod foundation coiling is generally to be found associated with interlocking stitches (fig. 5). In view of the undoubted Basket Maker type provenience of the prehistoric basket on which this one-rod coiling without interlocking is found, the implication seems to be that when peoples who made Basket Maker type work attempted one-rod coiling, their noninterlocking convention was carried over. This seems to me to support the theory that the one-rod coiled baskets with interlocking stitches are intrusive where they are found associated with Basket Maker or Cliff Dweller material.

The basket in sifter coiling of type A (fig. 8) which comes from Grand Gulch has several courses of one-rod foundation coiling with interlocking stitches (fig. 5) around the rim. If, on the basis of the foregoing, the one-rod coiled baskets with interlocking be considered intrusive ware, the sifter baskets of type A must also be considered intrusive. It is of interest in this connection that although sifter coiling of type B (figs. 6, 7, 17) has a wide distribution in the world, being found even in modern Mexican native work, in a specimen from San Salvador, and in characteristic work of Samoa and other places in the South Seas, I know of only one analogy to sifter work of type A, and this is only a partial similarity, viz, basketry made in Tierra del Fuego.[1]

The basket in the Wetherill collection from either southern Utah or southwestern Colorado, which is made in Basket Maker type coiling

[1] See Mason, p. 258, fig. 59, and p. 531, fig. 204.

on a two-rod-and-bundle-triangular foundation (fig. 2), but which has been repaired by setting in a bottom coiled on a one-rod foundation with interlocking stitches (fig. 5), again indicates the contemporaneity of the two techniques. In the light of the above discussion of the intrusive character of the one-rod coiling with interlocking stitches, it should be noted that while this bottom shows interlocking stitches, it is not part of the basket, but an attached piece.

Two exceptional specimens are known. There is first the specimen from Sandal Cliff House, Mancos Canyon, in double coiling on two-rod-and-bundle vertical foundation (fig. 13); double coiling is limited in modern times to San Carlos Apache and Salinan. The second is the specimen of wrapped coiling from Bear Creek on Blue River, which resembles Mohave work (fig. 18).

CONCLUSIONS

The most important implication of the above seems to be the strong evidence of a unified San Juan area in which Basket Maker material is concentrated, with more divergent types appearing at the periphery.[1] The outstanding Basket Maker types associated with this area are the close coiling with noninterlocking stitches on two-rod-and-bundle-triangular foundation (fig. 2) and two-rod-and-reed-triangular foundation, the sifter coiling of type B (figs. 6, 7, 17), and the twill-plaited baskets with open bottom. Associated with this area but perhaps intrusive are the coiled baskets with interlocking stitches on one-rod foundation (fig. 5) and the sifter coiling of type A (fig. 8).

The outstanding Cliff Dweller types are the close-coiled basketry of Basket Maker type technique with finer texture and the yucca-ring baskets (fig. 4). The apparent Cliff Dweller traits of the so-called "Ancient Pueblo" coiled basketry is supported by the persistence into modern times of the making of yucca-ring baskets, a Cliff Dweller trait, at Hopi (Second Mesa) and the Rio Grande pueblos.

The close coiling with noninterlocking stitches of fine texture on three-rod-triangular foundation (fig. 11) is a basketry type that is independent of the Basket Maker—Cliff Dweller complex. Its distribution is more southern, and it seems to be related to a later culture horizon. The type is identical with the modern coiled basketry of the San Carlos Apache. This is the only modern parallel which is exact.

The close affiliation of Sikyatki with modern Hopi peoples is supported by the basketry evidence. The intrusion of twined ware is

[1] The specimens from caves in the Lower Rio Grande region are a striking exception to the concentration in the San Juan area of the Basket Maker type.

suggestive of possible purchase from Havasupai and Hualapai, or possibly Ute. The practise of purchasing Havasupai coiled baskets is current today among the Hopi.

The appearance of a distinct Texas type of coiled basketry south of the Lower Rio Grande probably marks the limit of the prehistoric Southwestern area.

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TECHNIQUES ILLUSTRATED

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GRAPHIC CORRELATION OF RADIATION AND BIOLOGICAL DATA

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Chief, Division of Radiation and Organisms,
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Chief, Division of Radiation and Organisms, Smithsonian Institution

In discussions of the relation of radiation to biological phenomena one frequently wishes to correlate transmission curves and the characteristics of common sources of light with the response curves of the biological phenomena. Although the facts involved are for the most part well known, they are scattered through the literature in such a way that it is difficult to form a clear picture of their interrelation without gathering this material together graphically. In order to meet this need the composite graph shown in Figure 1 has been developed. The accompanying explanation indicates the significance of each curve, and the bibliography at the end of the paper will enable anyone who wishes more detailed data to go immediately to the original sources.

As water is the chief constituent of most living matter, its transmission characteristics set definite limits for other than surface effects of radiation. It is perhaps significant that radiation therapy has found its effective wave-length regions in those ranges where transition takes place from negligible transmission to relatively great transmission. Such a region exists in X rays from 1Å to shorter wave lengths, and again in the ultra-violet for wave lengths immediately longer than .18μ. Another region which has as yet been little studied occurs in the near infra-red for wave lengths shorter than 1.4μ. The transmission characteristics of water may perhaps most readily be indicated by plotting the absorption coefficients, that is k in the expression $I=I_0e^{-kx}$, as a function of wave length or frequency over the regions of interest. The full line curve a in the upper section indicates these values for the range from 10μ to .1μ in wave length as indicated at the bottom of the graph, or .1 to 10, $\times 10^4$ wave number (waves per cm, *i. e.*, proportional to frequency) as indicated at the top. The values of the absorption coefficients are shown at the left outside the frame. Another convenient method is to indicate for each wave length or frequency the thickness of water which will reduce the light to one-half

EXPLANATION OF FIGURE 1

Upper Section: ABSORPTION.

a ———— Water, ultra-violet, visible, and infra-red.

Ordinates: Absorption coefficients k in $I = I_0 e^{-kx}$ (outside left).
Thickness transmitting half intensity in cm (inside left)
Transmission of 1-cm thickness (right).

Abscissae: Wave lengths in microns μ (bottom).
Wave numbers, waves per cm (top).

b - - - - - Water, X ray (same ordinates).
Wave lengths in Angstroms (instead of μ as indicated at bottom).

c -·-·-·- Ozone, (same coordinates as in *a*; gas at standard conditions).
Atmospheric transmission is equivalent to about 3 mm and can be found by shifting scale (right) up by approximately half a division.

Middle Section: RADIATION.

Relative emission from body at 1,000° K. (dull-red therapeutic lamp).

Relative emission from body at 3,000° K. (high-temperature Tungsten lamp).

Relative emission from sun.

Relative emission from mercury arc in quartz.

Lower Section: BIOLOGICAL PHENOMENA.

a, transmission of flesh (1/2 cm thick) in per cent.

b, relative visibility.

c, relative phototropism.

d, Vitamin A.
Absorption and vitamin value disappears when radiated.

e, Ergosterol.
Absorption disappears under radiation, which produces activation yielding therapeutic value of vitamin D.

f. Relative erythema effectiveness, zero degree (very light). For extreme erythema, fourth or fifth degree, the relative intensities of the the two maxima are reversed.

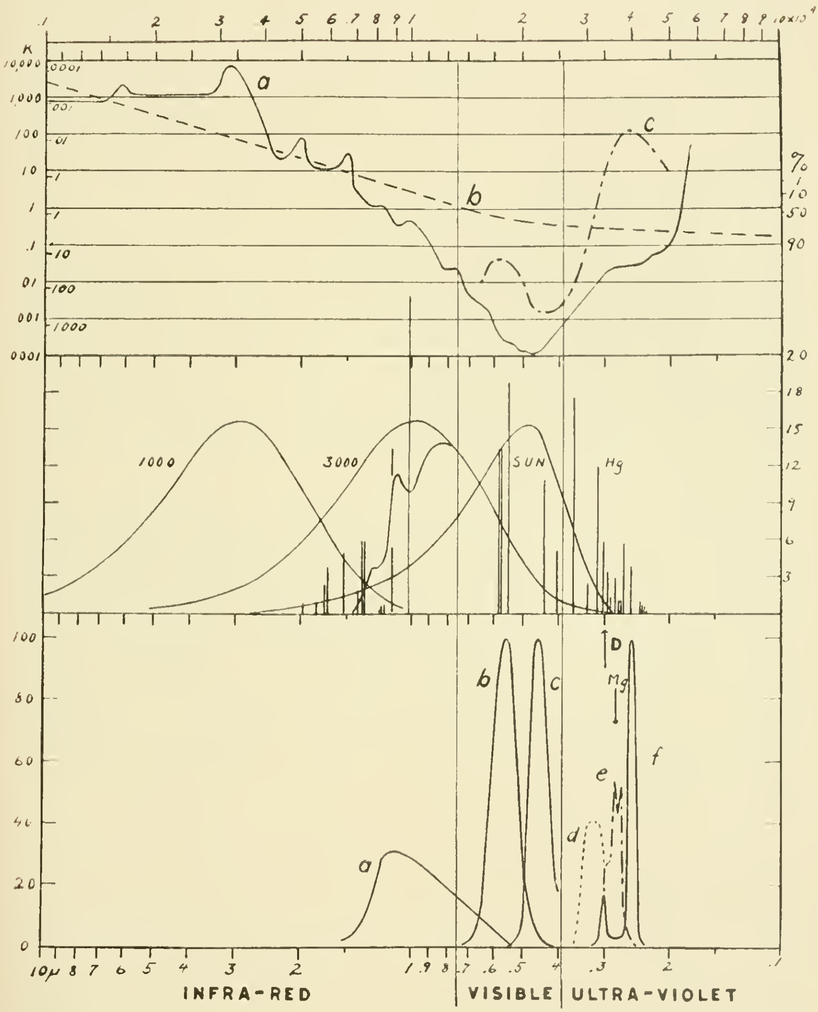

FIGURE 1.

its incident intensity value. These may be found from the same curve by reference to the ordinates at the left within the frame.

Thus at the limit of the visible in the red we find that some 30-cm water path is required to reduce the intensity of light to one-half its original value, whereas at $1\frac{1}{2}\mu$ only .03 cm or .3 mm will produce the same result. As water cells are frequently used of 1-cm thickness it is convenient to indicate the wave-length range over which such a cell will yield appreciable transmission. The values of transmission for 1-cm path are indicated at the right of the upper section. These enable one to immediately estimate the wave-length range for the cut-off from such a cell.

In order to compare the absorption characteristics which are familiar to radiologists in the X-ray range with those exhibited in the visible range the X-ray values have been indicated by the dotted curve *b,* the wave lengths being found by reading Angstroms instead of μ at the bottom of the graph. It is interesting to note the relatively smooth transition from low to high transmission in the X-ray region compared with the highly selective characteristics exhibited in the infrared, visible, and near ultra-violet.

As the presence of ozone in the atmosphere plays an important rôle in limiting the light which reaches the earth, the transmission characteristics of ozone gas under standard conditions have been indicated by curve *c.* The transmission values at the right now apply to a cell of 1-cm thickness of ozone gas under standard conditions. Since, however, the whole absorption in the atmosphere is equivalent to about 3 mm, in order to estimate the absorption of atmospheric ozone it is necessary to shift the transmission scale bodily upward by one-half of one of the large spaces indicated. We thus find the transition from 90 per cent to 1 per cent occurring in a very narrow region from 3,200 A to 2,950 A respectively.

With these curves in mind we may now profitably turn to the matter of sources of radiation with which one has commonly to deal. For the sake of comparison we have assumed that lamps will be chosen of such a size and used at such a distance that a comparable amount of maximum energy is received. The curve at the left shows the relative emission per unit wave length of radiation at each wave length for a solid body at the absolute temperature of 1,000° K. Here we find most of the energy occurring for wave lengths longer than 1.4μ, or, in other words, in a region where practically all the energy will be absorbed in an extremely thin layer of water. The customary dull red therapeutic lamp has characteristics not greatly different from this curve. For that reason it must be regarded for the most part simply as a surface heater.

The next curve indicates the emission of a solid body at an absolute temperature of 3,000° K, where it is now seen that its maximum energy lies in a region which would be relatively well transmitted by water. Such a radiation might well be expected to penetrate somewhat into the living matter. It does, however, contain a considerable proportion of energy which will be absorbed in a thin layer, that is for wave lengths longer than 1.4μ. If one wishes radiation that is as nearly free as possible of this surface-absorbed energy, a light of this temperature should be used with a water filter. A modified curve is indicated terminating at approximately 1.4μ, which shows the type of radiation which one would receive from an ordinary high-temperature lamp such as the customary Tungsten light when equipped with a water cell of 1-cm thickness. Again, on approximately the same scale the relative distribution of solar energy is shown as it would be without atmospheric absorption. Owing to atmospheric ozone no appreciable ultra-violet reaches us from the sun beyond 2,950 A. As the amount of ozone fluctuates this limit varies considerably. Furthermore, large amounts of energy are absorbed in the infra-red by atmospheric molecules, particularly water vapor. This, again, is subject to extreme variations, depending upon the location, time of day, and amount of humidity. In the solar curve we see that the chief energy lies in the visible region, whereas our high-temperature lamp, even with a water filter, has the larger proportion of its energy in the near infra-red. Since for therapeutic purposes the mercury arc is very widely used, its energy distribution has also been shown. As its light is radiated chiefly in a large number of restricted regions of practically monochromatic light, it can best be shown simply by vertical lines. The height of these lines is proportional to the intensity. Since, however, they differ widely for different conditions of excitation, they must be regarded at best as only a rough basis for estimation.

In addition to the blue and ultra-violet lines with which we are chiefly concerned, this arc shows not only strong yellow and green lines, but in most cases a line at 1.014μ of an intensity which exceeds any other line. This great line in the near infra-red occurs in a region where it is readily transmitted by water and, as we shall see in a moment, to a great extent by flesh. This wave length of radiation is readily transmitted by the aqueous humor of the eye and will be chiefly absorbed in the retina. While undoubtedly ultra-violet effects would be noticed long before any danger would be incurred from this radiation in the case of a quartz mercury arc, on the other hand in the case of ordinary glass mercury arc caution should be used to avoid too great exposure as it may produce a lasting injury in the nature of an actual burn on the retina.

In order to be able to correlate these physical characteristics which we have indicated with the direct observations of biological material, the lower portion has been devoted to characteristics for which data is available. Curve *a* shows the transmission of flesh, having been corrected for surface absorption. On the long wave-length side undoubtedly water is most important in setting the limit. On the short wave-length side other constituents of the living matter account for the fact that this transmission drops off rapidly on passing into the visible range. It will be noticed, therefore, that the region of the maximum transmission of flesh occurs roughly in the range emitted from a water-filtered high-temperature light. The near infra-red thus constitutes a region of relatively penetrating radiation for therapeutic purposes. Curve *b* shows relative visibility of light for the human eye. Curve *c* shows the relative phototropic response of an oat seedling to light. It will be noticed that it is insensitive to red and a considerable portion of the yellow, the maximum occurring in the blue. Curve *d* shows the absorption band that seems to be correlated with vitamin A. Radiation that is damaging to the vitamin value causes a weakening in this band. Curve *e* shows the absorption band that seems to be correlated with ergosterol and vitamin D. Radiation that seems to produce activation destroys this absorption. Curve *f*, the full line curve, shows the erythema response of the human skin in the case of a very light erythema (zero degree). Here it will be seen that a minor maximum occurs at .298μ and a great maximum in the region of .253μ. In the case of extreme erythema, fourth or fifth degree, the relative effectiveness of these two regions is reversed, the great maximum occurring at .300μ and the smaller maximum at the region of .253μ. It is, however, very significant and perhaps important from a therapeutic standpoint that a minimum of erythema occurs between these two ranges and that this minimum coincides with the chief ergosterol absorption. It may thus be possible to secure a maximum therapeutic dosage with a reduction in resulting erythema by the use of monochromatic light in this range. The magnesium spark lines at .280μ are promising for this purpose.

Another point of interest is that the lethal region for algae occurs in this same range as ergosterol absorption, the threshold for this effect being indicated by the arrow marked D. The solar energy falls off rapidly at this point.

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(WITH TWO PLATES)

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(PUBLICATION 3172)

CITY OF WASHINGTON
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(With 2 Plates)

Long ago, Secretary Langley induced Congress to support the study of solar radiation at the Smithsonian Astrophysical Observatory. He pointed out that all life and all weather depend on it. He held out the possibility and hope that a sufficient knowledge of solar radiation and of its behavior in our atmosphere might even enable meteorologists to forecast long in advance the fat years and the lean years as Joseph is said to have done in Egypt.

After 40 years of research, we have results which seem to us to justify in some degree Langley's hope. We have not yet, it is true, tried the bold venture of long-range forecasting, but we have evidence to present to the Academy today that the sun's output of radiation is variable; that its variation is periodic; that the United States weather departures from normal are periodic; and that nearly all of the ranges of weather departures from normal are comprised in a series of periodicities which are identical with those found in the sun. We expect to discover by a little more research whether we have here real cause and effect. If it should prove so, we need not emphasize the value of such knowledge.

For more than 25 years the staff of the Smithsonian Astrophysical Observatory has been measuring the intensity of solar radiation. At first, in Washington, we further developed the method devised by Langley and used by him about 50 years ago at Allegheny and at Mount Whitney. We devised the silver-disk pyrheliometer for ordinary daily measurements of the total intensity of solar radiation at the station. We also devised the water-flow and the water-stir standard pyrheliometers, whereby we reduced the scale of measurement to

[1] Paper presented before the National Academy of Sciences, April 26, 1932

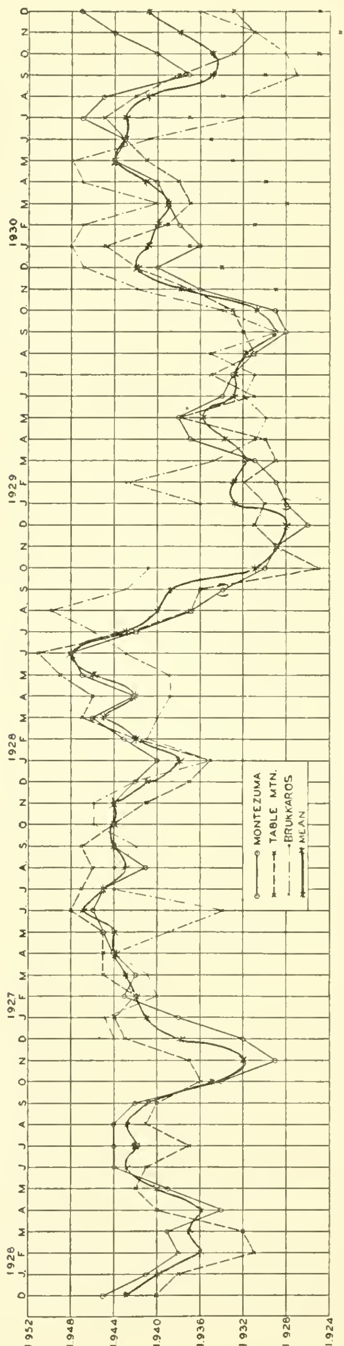

FIG. 1.—Solar variation as determined independently at three remote stations on high desert mountains.

standard calories per square centimeter per minute. We improved the recording spectrobolometer of Langley so that in less than 10 minutes it could furnish an excellent record of the intensities of all wave lengths in the solar spectrum from about 0.35 micron in the ultra-violet to about 2.5 microns in the infra-red. We devised graphical methods

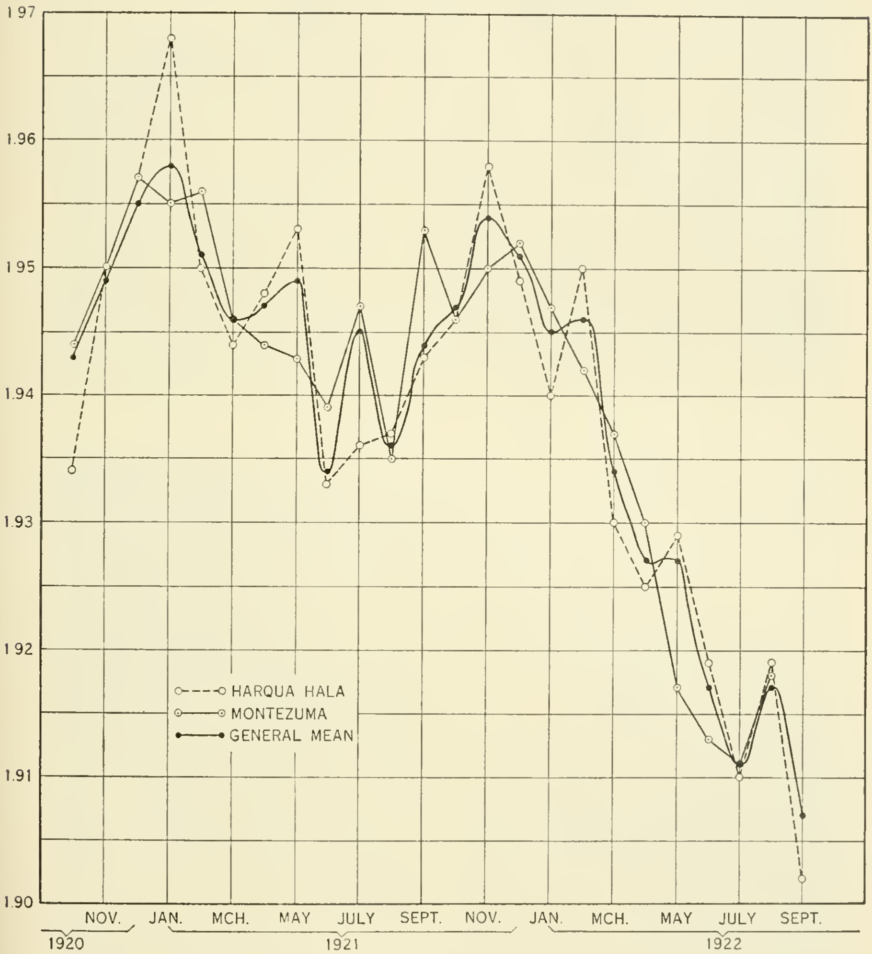

FIG. 2.—Solar variation 1920-1922 showing great change in 1922.

operated by instrumental appliances whereby we were able to compute the intensity and distribution in the spectrum of the solar radiation as it is outside the atmosphere, whenever we determined the intensity and distribution of it as it reached the surface observatory at different solar altitudes. We devised an instrument for measuring the brightness of the sky about the sun, which we named the pyranometer. By its aid we have devised a brief empirical method for estimating the atmospheric transparency in all wave lengths. We have also devised a spectroscopic method for estimating the quantity of precipitable water held in the form of vapor in the atmosphere. From our determinations of atmospheric transparency we have checked exactly with other methods on the determination of the number of molecules per unit volume.

As the temperature of the earth and the fundamental factors of climate and weather depend on the intensity of solar radiation, we have made earnest efforts over a long period of years to secure accurate measurements of it. When we began this work in 1903, authorities were in doubt over the entire range as between Pouillet's value of 1.76 calories, and Ångström's value of 4.0 calories for the solar constant of radiation. As a result of our work, carried on at all seasons, at stations ranging from sea-level to 4,500 meters elevation, and checked by automatic apparatus exposed from sounding balloons at 25,000 meters elevation, there is now no doubt that the true value lies certainly within one per cent of 1.94 calories per square centimeter per minute.

We have discovered evidences of variability of the sun's emission. Having devised a brief method of measuring the solar constant, we have applied it several times a day on all favorable days over a long term of years. We have occupied mountain stations in desert lands in Arizona and southern California, in northern Chile, and in South West Africa. Plate 1, Figure 1 shows our station at Mount Montezuma in northern Chile, 9,000 feet above sea-level. Plate 1, Figure 2 shows a closer view of the apparatus. The pyrheliometers and the pyranometer are exposed outside, and the solar altitude is measured with a theodolite. A beam of light is reflected into a cave observatory where the spectrobolometric work is done. Figure 1 shows the close accord attained in the monthly mean values of the solar constant at three widely separated stations. It is clear that if the observations at the earth's surface and the estimates of losses in the earth's atmosphere were correctly made, then determinations of the solar constant (that is, the intensity of solar radiation outside the atmosphere) ought to agree exactly wherever made on the earth's surface. In fact we have so far refined our determinations that our two best widely separated observatories, Montezuma, Chile, and Table Mountain, Calif., do agree in their monthly mean values over a period of five years within an average difference of 0.08 per cent. The probable error of the mean curve shown in Figure 1 is well below 0.1 per cent.

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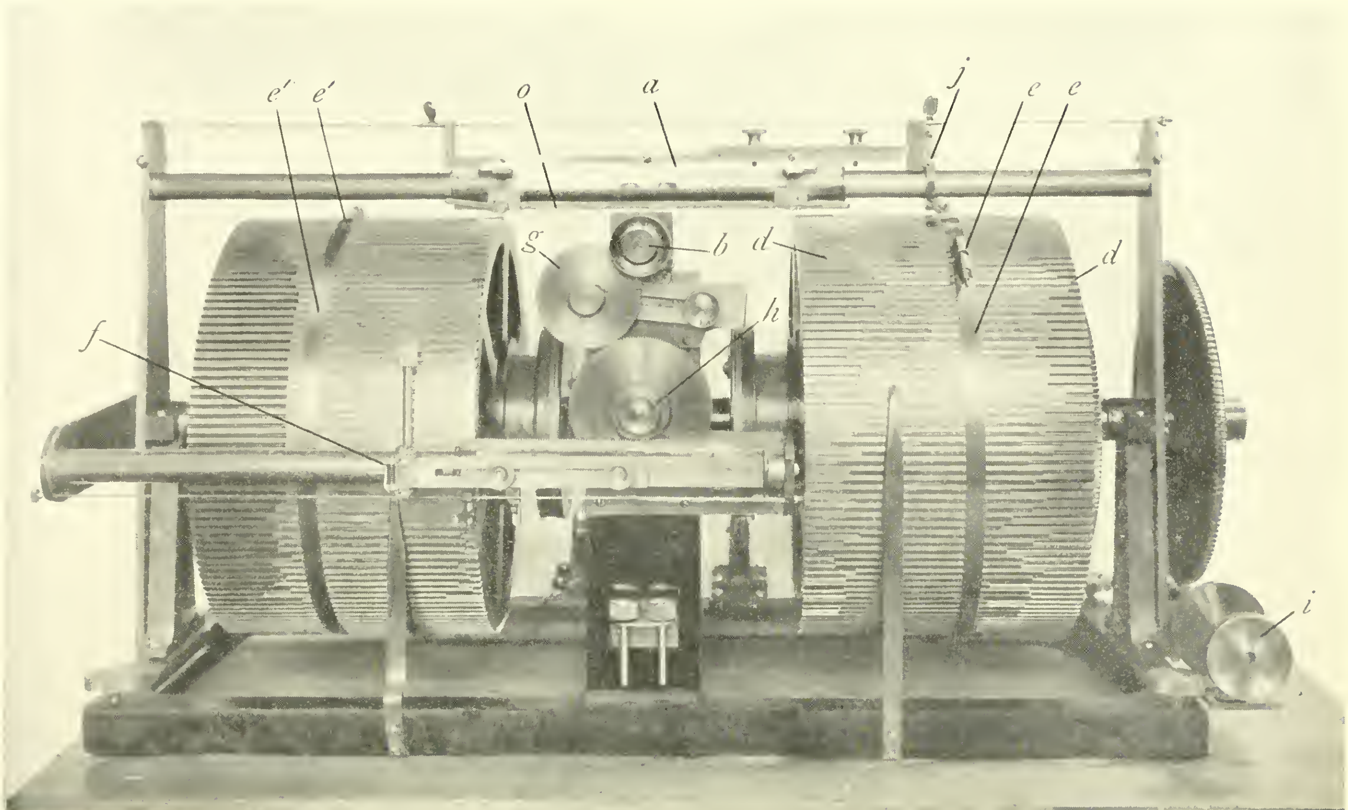
2

Solar radiation station, Mount Montezuma, Chile.
1, The dwelling; 2, the cave observatory.



The periodometer, an instrument for detecting and evaluating periodicities in long series of data. (For description, see Smithsonian Misc. Coll., vol. 87, no. 4, 1932.)

It will be noted that the three stations not only agree closely, but unite to indicate fluctuations of the sun's emission. The extreme range of variation shown in Figure 1 is 1.2 per cent. On an earlier occasion, in 1922, a range of the monthly mean values of nearly 3 per cent was observed as indicated in Figure 2, where values from Montezuma,

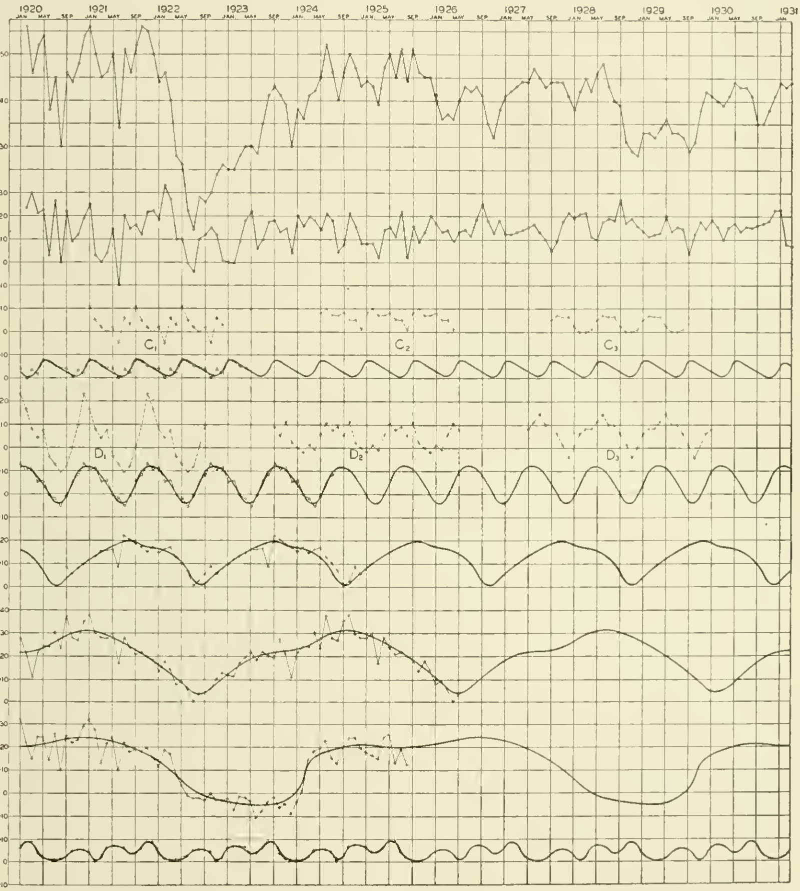


FIG. 3.—Solar variation, 1920-1930, composed of seven regular periodicities of 7, 8, 11, 21, 25, 45, and 68 months interval, respectively. A, original data; C, 8-month; D, 11-month; E, 25-month; F, 45-month; G, 68-month; H, 7 and 21-month; B, residual after removing all periodicities.

Chile, and Harqua Hala, Ariz., are compared. Taking the best results of the work as derived from the evidence of all stations, we find the variation of monthly mean solar-constant values since 1920 as indicated in Figure 3, curve A. We are able to reproduce it as the sum of seven regular periodicities of 7, 8, 11, 21, 25, 45, and 68 months. The degree of approximation is shown by the smallness of the residuals in curve B. It is to be noted that larger residuals are found in the earlier years when the solar observing was less perfected than it became later.

These results on periodicities have been obtained by Mrs. Bond with an instrument which we call the periodometer, shown in Plate 2. It was constructed with the aid of a grant of $1,000 from the Research Corporation of New York. Its purpose is to discover and evaluate periodicities in long series of observations. It does not recognize the reality of any period until tested, and it evaluates its distribution in amplitude without regard to any assumed mathematical expression. It appears to us, for instance, that as the curve of sun-spot frequency is well known not to be of regular sine form, there is no reason to suppose that other solar periodicities should have a sine form. Hence our instrument is designed to evaluate their forms as Nature fixed them, not according to the forms assumed in mathematical series and harmonic analyzing machines.

Curves C, D, E, F, G, H, of Figure 3 show the periodicities actually discovered in the solar radiation by aid of the periodometer. It will be seen that the 21-month period betrays also one of 7 months. In the cases of the shorter periods, we have been able to separate the data into several groups and independently evaluate the periodicities at several epochs. These partial determinations are shown in curves C_1, C_2, C_3, D_1, D_2, D_3. In such cases we have been encouraged to find that the maxima and minima occur without change of phase in these independent epochs. Thus we regard the periodicities found as having reality and permanence. We ventured in November, 1930, to make a forecast for 1931 and 1932 of the probable march of solar variation.[2] Thus far it has been well verified, although it called for solar-constant values almost all the time since 1930 about one per cent above the mean, notwithstanding that the values preceding the date of forecast for several years had been prevailingly below the mean.

It has been of great interest to us to note that several of the periodicities found in solar variation are closely related to the sun-spot period of $11\frac{1}{4}$ years or 135 months. Thus, 68 months is within its probable error one-half, 45 months one-third of 135 months. Again, if we take a period approximately three times as long, or 400 months, which is near the Bruckner period, 25 months is one-sixteenth, 21 months closely one-nineteenth, 11 months closely one-thirty-sixth, 8 months is one-fiftieth, and 7 months one-fifty-seventh of its duration.

If we admit provisionally (subject to the findings of subsequent years) that the solar variation is made up of the seven periodicities

[2] See Smithsonian Misc. Coll., vol. 85, no. 1, fig. 3, I, 1931.

named, it becomes of interest to see if these same periodicities are traceable in temperature departures of the weather. We have investigated this question for three widely separated United States stations,

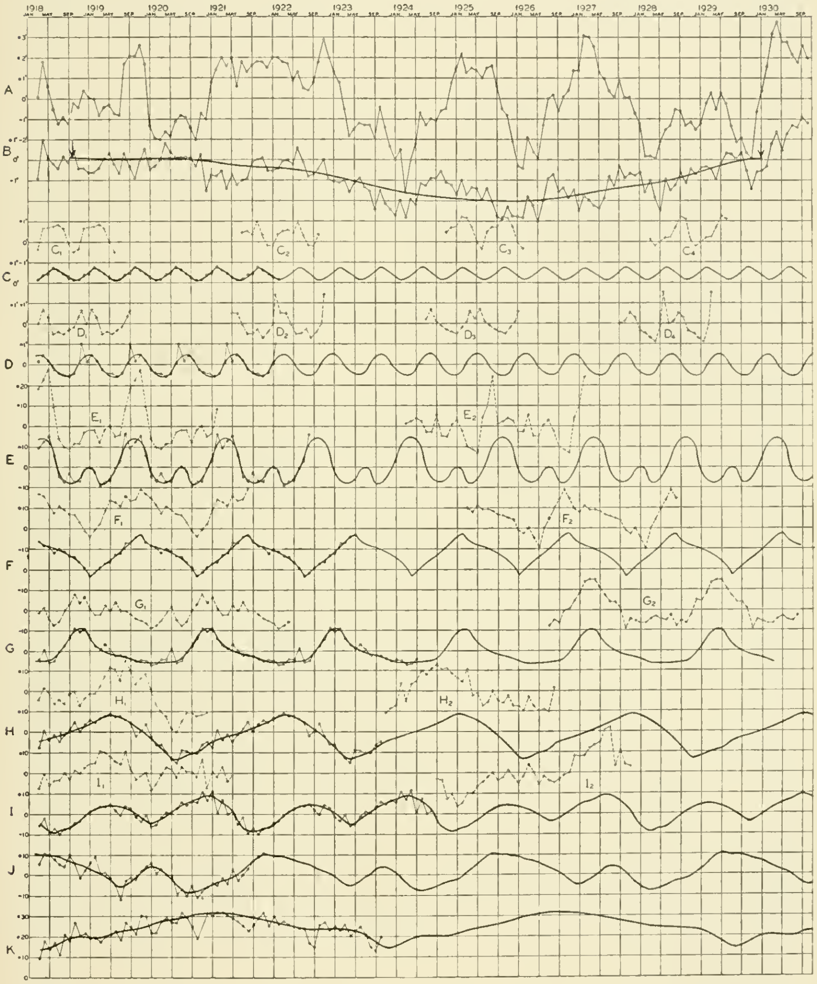


FIG. 4.—Temperature departures, Clanton, Ala., and their periodicities. A, original data; C, 8-month; D, $9\frac{1}{2}$-month; E, 18-month; F, 21-month; G, 25-month; H, 34-month; I, 39-month; J, 45-month; K, 68-month; B, residual after removing periodicities, shows $11\frac{1}{4}$-year periodicity.

viz.: Clanton, Ala.; Washington, D. C., and Williston, N. Dak. We have taken our data from the climatological summaries of the United States Weather Bureau, 1918 to 1930. In order to eliminate the yearly march of temperature, we have computed for each station the mean monthly temperatures 1918-1930, and have subtracted them from the observed, thus giving monthly departures exactly suited to the epoch studied. Lest the influences of shorter-period changes should obscure the general march of events, we have smoothed the monthly temperature departures by taking five-month consecutive means of the form

$$\frac{a_1+a_2+a_3+a_4+a_5}{5};\ \frac{a_2+a_3+a_4+a_5+a_6}{5},\ \text{etc.}$$

With the data thus prepared, we have sought and evaluated with the periodometer all the periodicities which the curves disclosed. Our procedure, as in the case of solar variation, is to subtract from the data the effect of each periodicity as soon as determined, before proceeding to evaluate in the residual curve another periodicity. We continued the search and evaluation until no more periodicities could be perceived.

The result obtained for Clanton is shown in Figure 4. Periodicities of 8, 9½, 18, 21, 25, 34, 39, 45, and 68 months were evaluated. These periodicities and their partial determining curves are indicated by letters C, D, E, F, G, H, I, J of Figure 4. The residual shown in curve B plainly indicates the 11¼-year period. We also note the large positive departure shown in the residual curve B for the year 1930, a year remarkable for the extraordinary drought and accompanying cloudlessness. A similar extraordinary positive departure for 1930 is shown in Figure 5, curve B, for Washington, and also in Figure 6 for Williston. It will be noted that strong periodicities of 8, 21, 25, 45, and 68 months found in Clanton temperatures are found also in solar variation. The 11-month solar period is indistinct in Clanton temperatures. The 135-month period is doubtless of solar origin, although it does not appear conspicuously in the solar variation between 1918 and 1930. The other Clanton temperature periodicities of 9½, 18, 34, and 39 months were not found in the sun, but nevertheless 34 months is one-half of 68 months, which is conspicuously found as a periodicity in the sun.

The results for Washington are shown in Figure 5. Periodicities of 8, 9½, 13½, 18, 25, 45, and 68 months are found as indicated at C, D, E, F, G, H, I. The residual curve B shows clearly the 135-month periodicity in practically the same phase, though lesser amplitude, than Clanton. The extraordinary drought of 1930 produces its strong positive departure. Here again the strong periodicities of 8, 25, 45, and 68 months seem to reflect solar-radiation changes. The periodicities of

9½ and 18 months are found also at Clanton. The 13½-month periodicity is new. No appreciable influence of the 11-month solar periodicity is found.

The results for Williston, N. Dak., are shown in Figure 6. Much wider range of departures is shown by curve A than by the correspond-

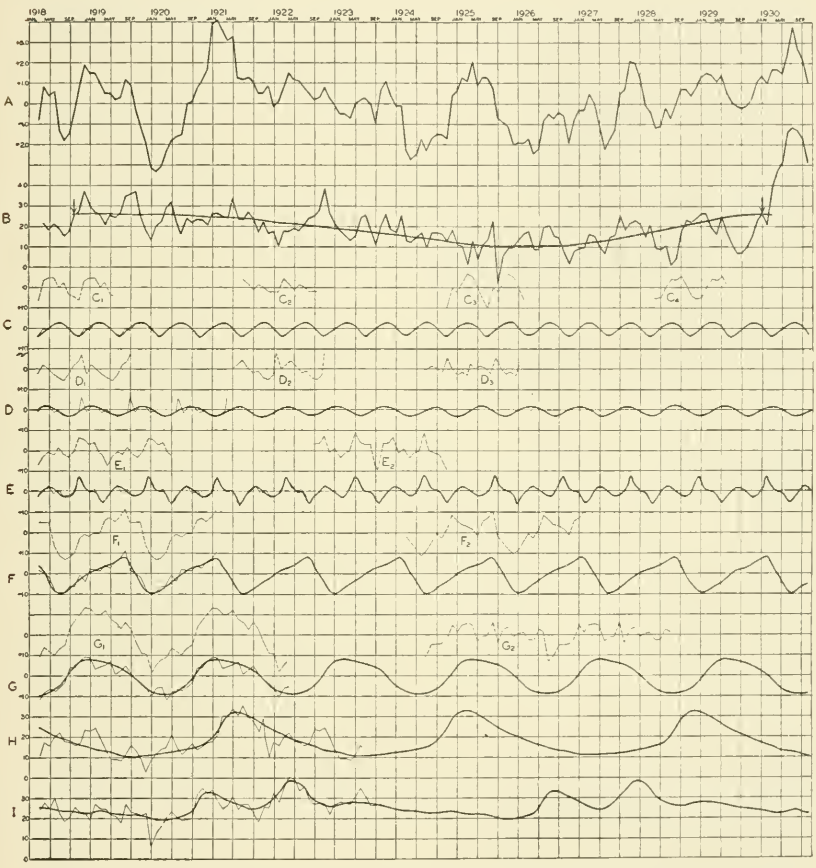


FIG. 5.—Temperature departures, Washington, D. C., and their periodicities. A, original data; C, 8-month; D, 9½-month; E, 13½-month; F, 18-month; G, 25-month; H, 45-month; I, 68-month; B, residual after removing periodicities, shows 11¼-year periodicity.

ing curves at Clanton and Washington. Yet, as shown by curve B, this range is reduced nearly to zero by withdrawing the periodic departures discovered. They are shown in curves C, D, E, F, G, H, I, J, K, and L, respectively of 7, 8, 11, 13½, 18, 21, 25, 28, 45, and 68 months periods. The 11¼-year period is but indistinctly shown in the residual

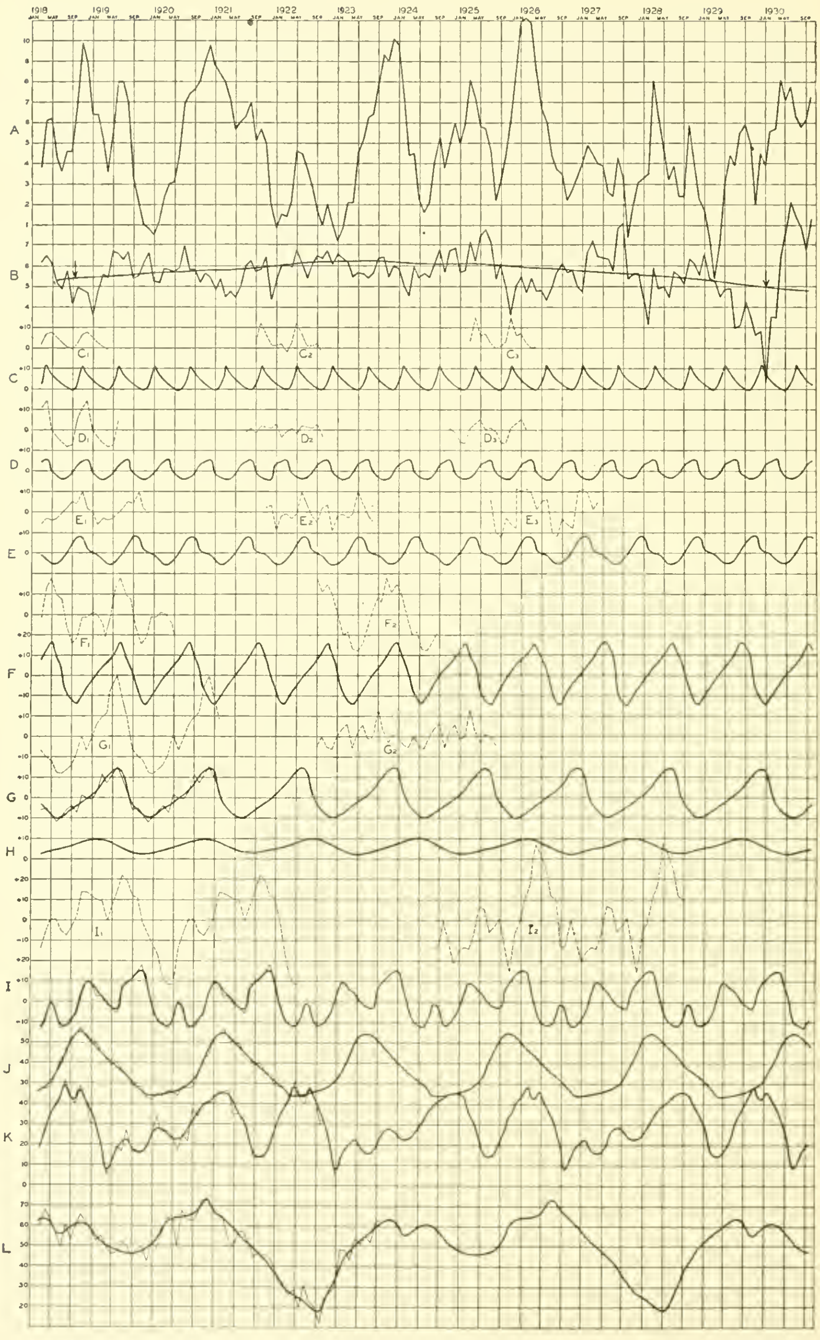


FIG. 6.—Temperature departures for Williston, N. Dak., and their periodicities. A, original data; C, 7-month; D, 8-month; E, 11-month; F, 13½-month; G, 18-month; H, 21-month; I, 25-month; J, 28-month; K, 45-month; L, 68-month; B, residual after removing periodicities, doubtfully showing 11¼-year periodicity.

curve B, and has a very different phase from corresponding curves at Clanton and Washington.

In order to fix our ideas of the relations between solar and terrestrial periodicities which we have discovered, we give in Table 1 a summary of them. We invite attention to the fact that a majority of the periodicities in terrestrial temperatures which we have found are identical in length with periodicities in solar variation. The sum of the maximum amplitudes of these periodicities which may be of solar causation is much greater than the sum of those which appear to be of terrestrial origin. In fact, if we make the hypothesis that a terrestrial temperature departure periodicity is of solar causation if it is of identical period with a solar periodicity, then we shall come to the result that nearly the whole magnitudes of the ranges of terrestrial temperature departures from normal used in our analyses are due to variations of solar radiation.

Table 1

Periods of solar origin months	Amplitudes of periodicities			
	Sun calories	Clanton ° F	Washington ° F.	Williston ° F.
7	0.005	...	...	1.2
8	.005	0.7	0.7	1.0
11	.009	...	...	1.3
21	.004	2.0	...	0.7
25	.010	1.6	1.7	2.7
45	.013	1.8	2.2	4.0
68	.014	1.8	2.0	5.5
135	....	2.0	1.5	0.7
Sum of amplitudes, solar		9.9	8.1	17.1
Periods of terrestrial origin months				
9½	....	1.0	0.5	...
13½	....	...	1.3	3.0
18	....	2.1	1.7	2.4
28	....	...	...	3.1
34	....	2.2	...	...
39	....	1.3	...	...
Sum of amplitudes, terrestrial		6.6	3.5	8.5

We do not venture to claim this important conclusion as yet. We intend to carry on the research much longer. But at least the investigation has decided promise.

We have been especially interested to compare among themselves the curves marked A in the four figures 3, 4, 5, and 6, giving the solar variation and the temperature departures at the three stations. We have also wished to compare the curves giving periodicities of 25 and 45 months in solar radiation with the corresponding temperature periodicities at the three stations. These comparisons are shown in Figure 7.

It appears at sight that parts of the curves of temperature departures for Williston and Washington are very similar, but that the similarity is slight as between Williston and Clanton. On the other hand, there are many points of similarity between the temperature departures of Washington and Clanton. The large departures of similar form found at Williston and Washington in the years 1918 to 1921 occur from one to two months later at Washington than at Williston.

Finally, we have made an experiment at long-range weather prediction. Instead of making our readers wait several years to test it, we have made our prediction backwards from 1918 instead of forwards from 1930, so that we could immediately compare expectancy with observation. Figure 8 shows the predicted and observed temperature departures from March, 1918, backward to September, 1916, for Clanton, Washington, and Williston. The agreement is not perfect, yet there is in each case a tendency to a correspondence in the trends. But it must be recalled that the periodicities found represent the *average* march of weather from 1918 to 1930, and therefore are to be regarded as of the epoch 1924. None of the periodicities fits this entire long interval of 13 years perfectly. Hence in predicting backward to 1917 we are really attempting a seven-year forecast from 1924. It is perhaps extraordinary that the correspondence is as good as it is. If our method should be used for serious long-range forecasting, it must be perfected so as to pass from the *last year or two* of known values to the unknown, not *seven years* as here attempted.

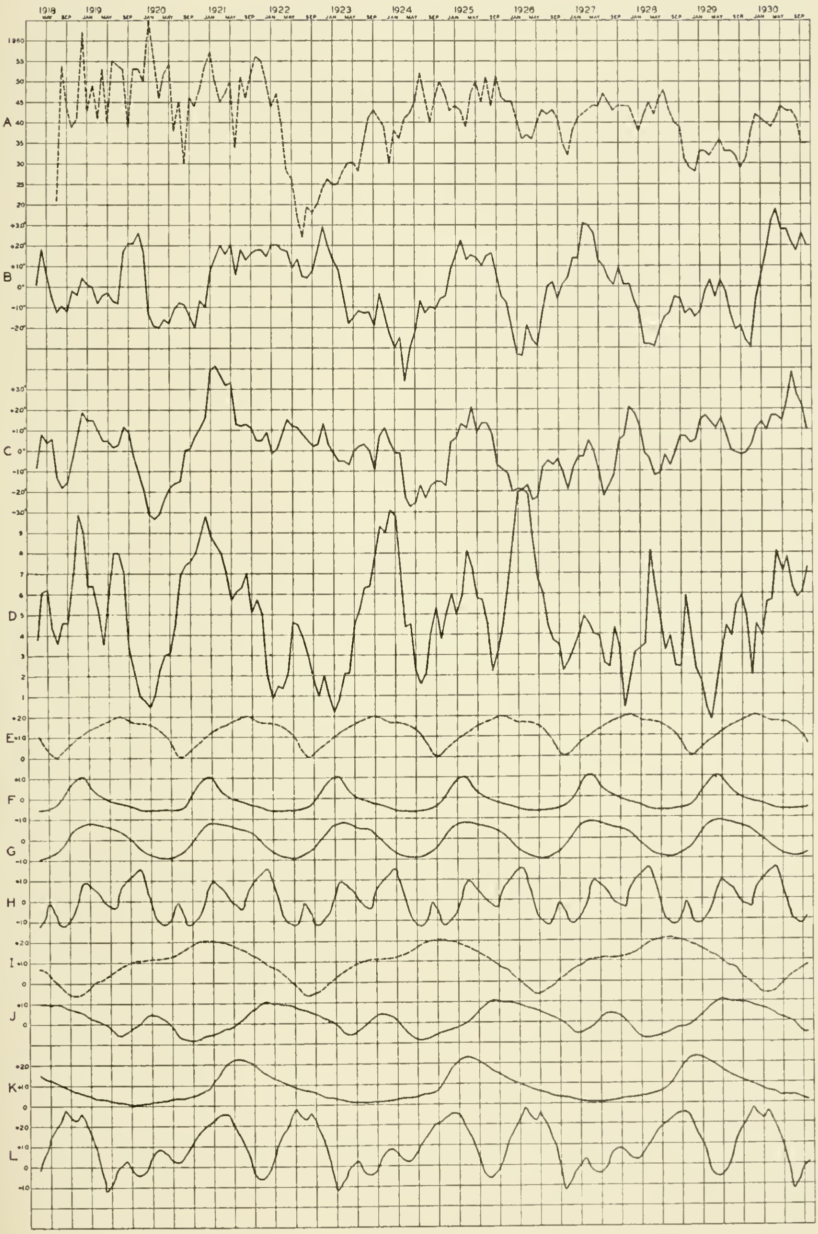


FIG. 7.—Comparison of solar variation with terrestrial temperature departures, curves A, B, C, D. Solar and terrestrial 25-month periodicities, curves E, F, G, H. Solar and terrestrial 45-month periodicities, curves I, J, K, L. Temperature stations: Clanton, Ala.; Washington, D. C.; Williston, N. Dak.

FIG. 8.—A retrograde temperature departure forecast from 1924 backward 1918-1916. Based on average periodicities in departures 1918-1930.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
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LETHAL ACTION OF ULTRA-VIOLET LIGHT ON A UNICELLULAR GREEN ALGA

(With Two Plates)

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FLORENCE E. MEIER
Division of Radiation and Organisms, Smithsonian Institution

(Publication 3173)

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LETHAL ACTION OF ULTRA-VIOLET LIGHT ON A UNICELLULAR GREEN ALGA [1]

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INTRODUCTION

The stimulative and lethal action of ultra-violet irradiation on higher and lower plants and animals has been the subject of interesting research during the past 50 years. Unfortunately, the lack of sufficient physical data makes a correlation of the various results difficult and often inconclusive.

An accurate determination of the action of ultra-violet light on plants and animals can be obtained only by the use of monochromatic light and by measuring its actual intensity at the surface of the organisms.

For the work described here a quartz spectrograph was constructed for the purpose of exposing algae under sterile conditions to monochromatic light and thereby observing the effectiveness of a wide range of wave lengths in a definite time. This spectrograph was designed by Dr. F. S. Brackett and was constructed in the shop of the Division of Radiation and Organisms of the Smithsonian Institution. A delicate thermocouple [2] made possible the unselective determination of the relative energy of the different wave lengths.

I wish to express my gratitude to Dr. C. G. Abbot, Secretary of the Smithsonian Institution, and to Dr. F. S. Brackett, Chief of the Division of Radiation and Organisms of the Smithsonian Institution, for their aid and suggestions. The work was done with the cooperation of Dr. E. D. McAlister of the Division of Radiation and Organisms, who carried out the spectroscopic manipulations and physical measure-

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[1] This paper reports investigations made under a grant from the National Research Council to the author as National Research Fellow in the Biological Sciences.

[2] The thermocouple of special design developed in the Division of Radiation and Organisms, similar to those described in the paper, The automatic recording of the infra-red at high resolution, by Brackett and McAlister, Rev. Sci. Instruments, vol. 1, pp. 181-193, 1930, was constructed by Dr. E. D. McAlister.

ments. In a paper in process of publication Dr. F. S. Brackett and Dr. E. D. McAlister will discuss more fully some of the physical problems that arise in connection with this work.

RESULTS OF OTHER INVESTIGATORS

The unicellular green algae, such as *Chlorella, Pleurococcus, Scenedesmus,* and *Chlamydomonas,* because of the similarity of their cells in size, shape, and contents when in pure culture, can be grown fairly homogeneously on a plate for exposure in the spectrograph. They thus form excellent material for the study of the effect of ultra-violet light.

As early as 1882 Engelmann placed green cells of *Oedogonium, Cladophora,* and other algae in the spectrum of a microspectroscope to observe the movement and accumulation of oxygen-loving bacteria in those regions most favorable to assimilation. He used a constant gas light and an incandescent electric light as sources of illumination. Because of the great light intensities he was able to use a narrow slit and so obtain a very pure spectrum. Ingenious as this method is, his values are only approximate. Pringsheim (1886) using the same general method found quite different values.

Ward (1893) exposed plates of agar uniformly covered with bacteria to the spectrum and then observed the behavior of the illuminated regions after incubation. He used the solar and " electric " spectra and found that no detrimental action was perceptible in the infra-red, red, orange, and yellow regions, but that all the bacteria were destroyed in the blue and violet regions and far into the ultra-violet.

Hertel (1905) was the first worker who made quantitative measurements of the intensities of monochromatic light used for ultra-violet radiation. His monochromator with its quartz prism and lenses was similar to those now used in ultra-violet microscopy. He determined the relative intensities of four lines of the ultra-violet part of the spectrum by means of a thermopile and he varied the intensity by regulating the amperage of the metallic arc. He found the region 2,800 A.[1] to have a very destructive action on paramoecia and bacteria.

In the past few years Cernovodeanu and Henri (1910), Browning and Russ (1917), Mashimo (1919), Bang (1905), Bie (1889, 1905), Bovie (1915), and a number of other workers have used the quartz spectrograph for the study of the bactericidal action of light. Raybaud (1909) made a spectrogram of three fungi. Hutchinson and Ashton (1929), and Weinstein (1930) have studied the effect of monochro-

[1] A. = Angstrom units. $1\mu = 1{,}000 m\mu = 10{,}000$ A. There are 100,000,000 A. to the centimeter.

matic light on paramoecia. Hutchinson and Newton (1930) have contributed quantitative data on the effect of irradiation on yeast. Bucholtz (1931) found that the cells of higher plants are more resistant to the lethal action of ultra-violet light than bacteria and paramoecia. Weinstein (1930), Bucholtz (1931), and many of the other authors have made comprehensive reviews of the literature on ultra-violet irradiation.

Of the recent investigators, Gates (1929, 1930) has most clearly demonstrated the value of the use of monochromatic light of different intensities in the study of the lethal effect of 10 lines of the mercury-vapor spectrum on bacteria. By the use of a specially constructed monochromator and a thermopile he found the wave-length limits of the bactericidal action to be between 3,130 and 2,250 A., although the lower limit could not be positively ascertained.

EXPERIMENTAL PROCEDURE

Chlorella vulgaris, the alga which was used in this experiment, is a unicellular green alga, the spherical cell containing a parietal chromatophore and one easily visible pyrenoid. The diameter of the cell is usually 3-5μ, although some giant cells exceed 10μ. It multiplies by oval or elliptical spores, usually two to four in number. This alga has been maintained in pure culture in my collection for two years.

The nutritive solution in which the algae were grown is Detmer 1/3, a modified Knop solution, made up in the following proportions and then diluted to one-third:

Calcium nitrate	1.	gram
Potassium chloride	0.25	"
Magnesium sulfate	0.25	"
Potassium acid phosphate	0.25	"
Distilled water	1.	liter
Ferric chloride	a trace	

Petri dishes 9.5 mm in diameter containing the above solution plus 2 per cent agar were sterilized in the autoclave at 15 pounds pressure for 20 minutes. When the media, which was about 4 mm thick, had solidified, a suspension of green cells of *Chlorella vulgaris* that had been growing in Detmer 1/3 solution in diffuse light was poured over the agar in the petri dish. This suspension of green cells was allowed to remain on the media for 24 hours, then the excess was poured off. The covered culture was placed under a bell jar and grown in diffuse light from a north window during the month of July. After a month's time the surface of the agar plate was covered with a quite uniform green growth of algal cells.

The cover was removed, and the lower part of the petri dish was immediately covered with clear cellophane that had been soaked in 99 per cent alcohol. The culture was then placed in position in the spectrograph. It is necessary that no absorbing medium shall be present between the measured incident energy and the exposed algae. However, Johnson (1931) found that the percentage transmission of cellophane as compared to air is close to 100. Browning and Russ (1917) have demonstrated that no difference can be detected in the density of the growth of bacteria over the irradiated and non-irradiated portions of agar; consequently, ultra-violet irradiation has no appreciable effect upon agar.

After exposure of 21 minutes to the spectrum the cover of a sterile petri dish was placed over the cellophane-covered lower dish and the petri dish culture was returned to the bell jar in diffuse light.

No change was observed in the growth of the algae on this first plate until one week after exposure. Then white lines resulting from the complete decolorization of the chlorophyll and death of the green cells corresponded to the typical mercury lines for all wave lengths shorter than 3,000 A. just as they would be seen on a photographic positive (see pl. 1).

A slightly different technique was developed for the preparation of subsequent plates for exposure in the spectrograph. The surface of a glass plate of dimensions 8 by 10 cm was ground so as to retain the agar poured on it. The plate was placed in a large petri dish 15 cm in diameter and covered with Detmer 1/3 agar 2 per cent, sterilized, and inoculated as described above with a suspension of green cells of *Chlorella vulgaris*. After a month's time the agar plate covered with green cells was cut out of the surrounding agar in the petri dish and placed upright in a closed sterile brass container with a quartz window. A decker was arranged in front of the slit of the spectrograph to permit the exposure of different portions of the plate for different lengths of time.

The second plate was subjected to five irradiation periods of 6 and 20 minutes, 1, 3, and 18 hours. When the plate was removed from the spectrograph at the end of 22½ hours the effect of the 18-hour exposure was clearly visible. Three lethal regions of the 3-hour exposure were also visible. Plate 2, Figure 1 is a photograph made of the plate as soon as it was removed from the spectrograph. The algal plate was placed in a sterile petri dish in a bell jar in diffuse light. Within two days the results of all five exposures were evident.

RESULTS

Decolorized regions appeared where the plate was exposed to wave lengths 2,536, 2,652, 2,699, 2,753, 2,804, 2,894, 2,967 and 3,022 A. Those algae exposed to wave lengths 3,130, 3,341, 3,650 A. were unharmed and the cells were filled with green chlorophyll. Furthermore, it may be noted that wave lengths 3,130 and 3,650 A. are more intense by actual thermocouple measurements, as shown in Table 1.

McAlister, by the use of the double monochromator and extremely sensitive thermocouples, has accurately measured the energy distribution in the mercury arc in the ultra-violet region between 2,000 and 4,000 A. In Plate 1 the first algal spectrogram obtained in this experiment is superimposed on McAlister's record of the mercury-arc spectrum. The ordinates given here in centimeters of galvanometer deflection are proportional to the intensities measured with the double monochromator. For quantitative comparison these intensities have been corrected for the relatively lower transmission of the fused quartz system of the spectrograph used in this experiment.

Table 1 gives the intensities of the lines used and the computation of the relative lethal sensitivity to each line. Duplicate natural-color plates were made of the first algal spectrogram which was exposed for 21 minutes over the entire length of the slit. Black and white copies of these color plates were then made, and a densitometer record was determined on a Moll recording microphotometer. The curves of the density of the silver in the photographic emulsion correspond here to the algal density. A photometer record was also made of the composite superimposition of the two negatives of the color plates, the photograph of which is shown in Plate 2, Figure 2. The areas under the photometer curves corresponding to the intensity of the lethal effect were measured with a planimeter. In cases where the plates were obviously so thin that the densitometer record appears as a truncated pyramid, extrapolation to a normal curve has been made in order to correct as far as possible for this source of error. The probability is that the stronger lines are still undercorrected. The average of the areas of these three densitometer records gives the best available data for the first traverse of the color plate.

A second traverse, that is, a densitometer record across another region of the plate, was made in order to obtain a better representative determination and so minimize the inhomogeneity of this plate. The uniformity in the second traverse is such that equal weight has been given to it with the average area determinations of the first traverse.

Mean area (A) is the average of the areas from the first and second traverses. These areas should give a reasonably good measurement

TABLE I

λ	2,536	2,652	2,699	2,753	2,804	2,894	2,967	3,022	3,130	3,341	3,650
Color plate:											
Intensity ergs/sec. cm²	480	2,050	530	480	1,930	970	2,610	5,700	12,600	1,450	28,000
First traverse:											
Negative 1 areas...	0.58	2.11	0.96	0.88	2.34	0.89	0.34	0.31	0.0	0.0	0.0
Negative 2 areas...	0.65	2.27	0.99	0.90	2.31	0.96	0.32	0.29	0.0	0.0	0.0
Composite areas ...	0.66	1.85	0.89	0.66	1.87	0.90	0.48	0.34	0.0	0.0	0.0
Average areas	0.63	2.08	0.95	0.81	2.17	0.92	0.38	0.31	0.0	0.0	0.0
Second traverse:											
Areas	0.31	1.65	0.86	0.60	1.52	0.44	0.44	0.15	0.0	0.0	0.0
Mean areas (A).....	0.47	1.87	0.91	0.71	1.85	0.68	0.41	0.23	0.0	0.0	0.0
Hg. rel. int. (B).....	2.0	8.5	2.2	2.0	8.0	4.0	10.8	23.6	52.4	6.0	115.7
Ratio $\frac{A}{B}$	0.24	0.22	0.41	0.35	0.23	0.17	0.04	0.01	0.0	0.0	0.0
Black plate:											
Intensity ergs/sec. cm²		1,550	530	480	1,930	970	2,610	5,700	12,600	1,450	28,000
Hg. rel. int. (B').............		6.4	2.2	2.0	8.0	4.0	10.8	23.6	52.4	6.0	115.7
Exposure 1:											
Areas A'		0.20	0.11	...	0.27	...	...	...	...	...	...
Ratio $\frac{A'}{B'}$		0.031	0.05	...	0.034	...	...	...	...	...	...
Exposure 2:											
Areas A''		1.64	0.77	0.61	1.75	0.87	0.97	0.61	0.00	0.00	0.00
Ratio $\frac{A''}{B'}$		0.26	0.35	0.31	0.22	0.22	0.09	0.03	0.00	0.00	0.00

of the lethal effect, for they should be proportional to the algae killed, within the limitations due to plate thickness and other possible causes. If these figures are divided by the relative intensity of the lines, an approximate value is obtained of the relative lethal effect of a given quantity of incident energy of different wave lengths. These values are given in the ratio $\frac{A}{B}$. While these values have been given to two figures for the sake of uniformity, the significance of the quantities differs greatly for different wave lengths. Values for wave lengths

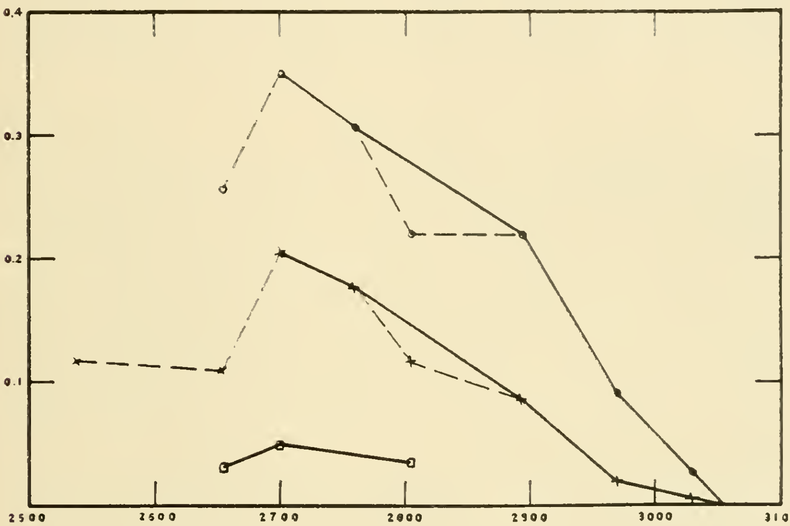

FIG. 1.—Relative lethal effect of ultra-violet light on *Chlorella vulgaris*. The ordinates are relative lethal effect in arbitrary units. The abscissae are wave-lengths in Angstrom units. (Dots occur through points of less weight.) ☐ Exposure 1, black plate; ○ exposure 2, black plate; × color plate.

2,536 A. should receive almost no weight because of the changing intensity due to the progressive opacity of the arc walls. Lines 2,652 A. and 2,804 A., because of the fact that they are both highly lethal and very intense, are rendered doubtful, since all the algae were killed over a wide range so that corrections for this thin plate effect are uncertain.

The black plate or second plate was taken some months later with the result that the wall of the arc had become so opaque that it was impossible to work with line 2,536 A. and the intensity of the line 2,652 A. was reduced by a quarter of its original value. Two exposures of different lengths were obtained on this plate and are shown in Plate 2, Figure 1. Exposure 1, which lasted three hours, gives an idea of the relative effects of lines 2,652 A. and 2,804 A., which are badly overexposed when adequate exposure is made for the weaker lines. Exposure 2 lasted 18 hours and shows perceptible lethal effect even in line 3,022 A., which was scarcely noticeable in the color plate.

The values of relative lethal effect for the color plate and each of the two exposures on the black plate have been plotted and are shown in Figure 1. Those points connected by dotted lines are to be given relatively smaller weight. Of course, it should be emphasized that these measurements are only approximate in that different periods of incubation and different times of exposure may modify the relative effects of different wave lengths. As the lines differ so greatly in intensity it is hoped that further investigation can be undertaken so that the effects of intensity and time exposure may be studied.

DISCUSSION

The ultra-violet component of solar radiation at the earth's surface is from the limit of the visible spectrum, 4,000 A. to about 2,950 A. In nature, plants are exposed to invisible radiations in this region.

The amount of ultra-violet light which the plant receives varies according to the altitude, atmosphere, and season of the year. Life as it is on the earth is possible only because of the ozone formed in the upper layers of the atmosphere by the action of the short wave lengths of the ultra-violet of sunlight on oxygen. This ozone serves as a light filter and thus protects the life on the surface of the earth from the shorter destructive rays.

Throughout the ages living organisms have probably become adapted to solar radiation as it is received on the earth's surface and very possibly with the same spectrum limit due to ozone. It is, therefore, not surprising that radiation of wave lengths shorter than the solar limit produce unusual effects. While large amounts of ultra-violet of certain wave lengths are lethal, it is possible that very small amounts of the same wave lengths may be not lethal but, on the contrary, stimulating to the growth of green algae. With further experimentation we hope to obtain more definite information in regard to the possibility of this stimulative effect.

SUMMARY

It is extremely interesting to note that in the regions where the ultra-violet waves beyond 3,022 A., the approximate limit of ultraviolet irradiation in nature, were directed on the culture, the green algal cells were killed. These lethal regions appear as decolorized cells in the green algal plate at the wave lengths 3,022, 2,967, 2,894 2,804, 2,753, 2,699, 2,652, and 2,536 A. Wave lengths longer than 3,022 A.,

that is the wave lengths 3,130, 3,341, and 3,650 A., had no appreciable lethal effect upon the algae. Yet by the thermocouple measurements a greater intensity of light was directed on the cultures at wave lengths 3,130 and 3,650 A.

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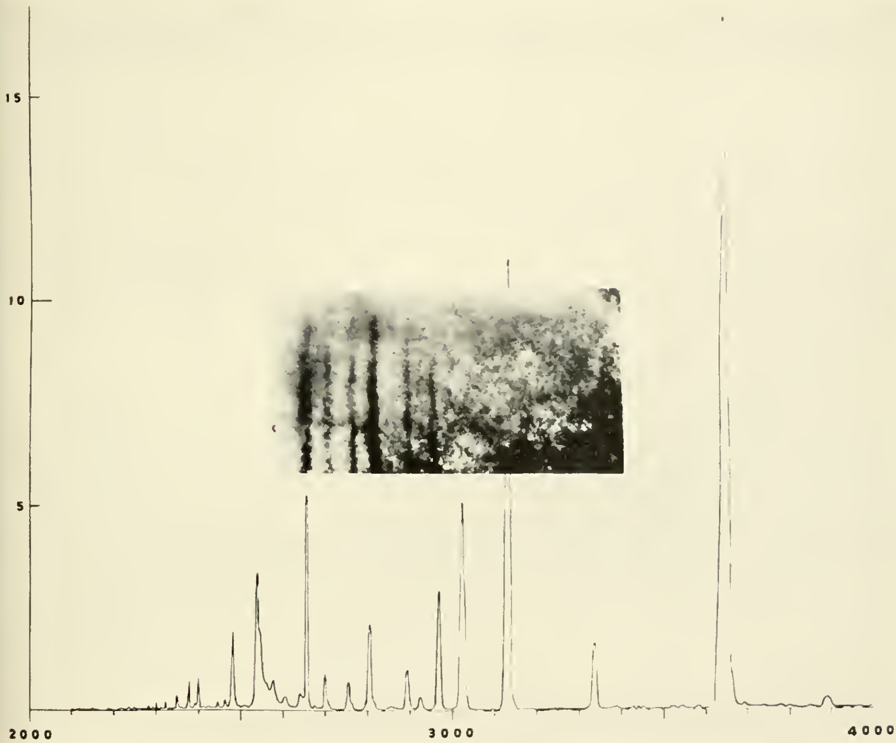
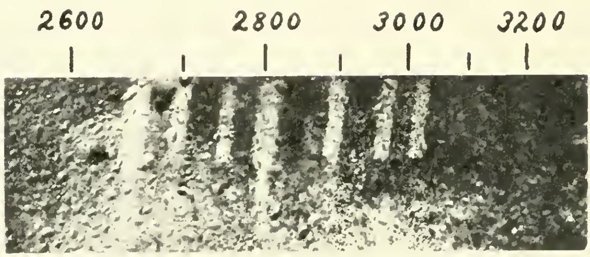
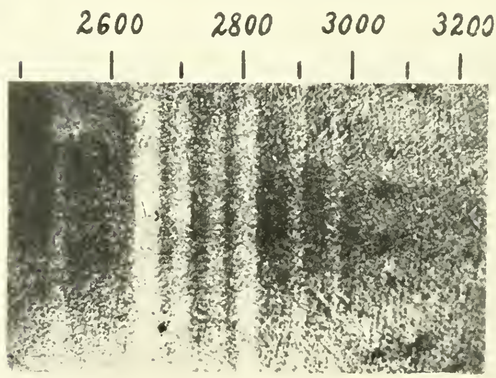


ALGAL SPECTROGRAM SUPERIMPOSED ON MERCURY ARC SPECTRUM

The ordinates are proportional to the intensity given in terms of galvanometer deflections in centimeters. The abscissae are wave-lengths in Angstrom units.



1. Black plate showing results of exposures of eighteen hours' and three hours' duration.



2. Composite of color plates showing results of exposure of twenty-one minutes' duration.

ALGAL SPECTROGRAMS

SMITHSONIAN MISCELLANEOUS COLLECTIONS
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REPORT ON ARCHEOLOGICAL RESEARCH IN THE FOOTHILLS OF THE PYRENEES

(WITH EIGHT PLATES)

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(PUBLICATION 3174)

CITY OF WASHINGTON
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During July and August, 1931, the Smithsonian Institution and the University of Toulouse carried on cooperative research in prehistory in the departments of the Ariège and Haute Garonne, France. The writer, on the staff of the United States National Museum, was Field Director and the Smithsonian representative, while Count Henri Begouen, Professor of Prehistory at the University of Toulouse, represented the University. The results of this cooperation were so satisfactory that an agreement has been signed between the two institutions which continues the work during a period of 10 years.

MARSOULAS

The cave of Marsoulas, situated on the southern side of an abrupt hill on the right bank of a little stream known as the Louin, in the Commune of Marsoulas, Haute Garonne, was chosen as the first site for excavation.

The cave, having its opening due west, was formed by the action of water along a fault in limestone containing algae and foraminifera, belonging to the Thanetian or base of the Nummulithic series of the "Petites Pyrenees."[1] Its present opening is 10 meters behind the original emplacement, and the terrace, previous to this year's work, was buried deep under humus and rock falls from the former roof and the hill above. The gallery runs almost due southwest-northeast into the hill to nearly 60 meters depth. At about 40 meters it dips sharply down for some 5 meters to a spring, beyond which it is blocked by clay infiltration. The spring, flowing under the gallery, issues from the hill below the entrance and becomes part of the Louin.

Earlier excavation, in 1885-86, had brought to light two levels of Magdalenian and one of Aurignacian age.[2] Of its yield, only a few

[1] The Smithsonian Institution wishes to express its thanks to Monsieur Mengaud, Professor of Geology at the University of Toulouse, who visited Marsoulas while excavation was in progress and gave the above determination.

[2] Abbé Cau-Durban, La Grotte de Marsoulas. Impremerie et Librairie Abadie, St. Gaudens, 1887. Cau-Durban erroneously calls the Aurignacian level Solutrean.

objects are extant, a collection of flint and rock-crystal artifacts and a few worthy examples of geometric and figured art on horn and bone[3] now to be seen in the Musée d'Histoire Naturelle at Toulouse.

In 1897, only a short time after the existence of Quaternary art had been established by the acceptance on the part of the scientific world of the authenticity of the polychromes in Altamira, M. Felix Renault announced the presence of frescoes in the gallery of Marsoulas.[4] These and many others, unseen by Monsieur Renault, were later published by Cartailhac and Breuil.[5] Among the geometric signs, polychromes, and engravings, the most outstanding are the well-known engraved human heads, the two dotted bisons in red and black, and the panel of aborescents, pectiforms, tectiforms, etc.

Shortly before his death, Monsieur Cartailhac purchased the cave and willed it to the University of Toulouse, after which it became a classified monument.[6]

While the interior of the cave was found to have been excavated, an entrance sounding at the emplacement of the modern gate erected by the University of Toulouse revealed an intact hearth apparently extending in front under the terrace. This was at first thought to be of Magdalenian age, but it later proved to be Aurignacian. Accordingly, the surveying zero was established on top of this hearth and the terrace was entirely removed. It contained four levels: Level 1, humus not quite 1 meter at its thickest; Level 2, averaging 2.25 meters thickness in the vicinity of the entrance, relic-bearing and composed of rock falls and earth; Level 3, bear clay;[7] Level 4, the present bed of the underground stream running from the spring in the back of the cave (pl. 1).

[3] Abbé Breuil, Les Sub-divisions du Paleolithique Superieur et leur Signification. Congr. Int. d'Anthrop. et Arch. Prehist. Comte Rendu XVI Sess., Geneve, 1912. Abbé Breuil et de St. Perier, Les Poissons, les Batraciens, et les Reptiles dans l'Art Quaternaire. Mason et Cie., 1927. Count Henri Begouen, Sur un Os Grave de la Grotte de Marsoulas. Rev. Anthrop., Oct.-Nov., 1930.

[4] Bull. Archaeol., p. 210, 1903.

[5] Cartailhac, E. et Breuil, L'Abbé H., Les Peintures et Gravures murales des Cavernes Pyrénéennes. Extract from L'Anthropologie, vols. 15 and 16, Mason et Cie., 1905.

[6] A "classified monument" is an archeological site or architectural monument which is classified by the French Government and protected by law from depredation or removal from France. The Smithsonian Institution wishes to express its thanks to the Beaux Arts Commission for Classified Monuments, who graciously gave their permission for excavation to be carried on in Marsoulas.

[7] The term "bear clay" is applied by prehistorians to a level occurring in the caves of this region, which contain the bones of the cave bear (*Ursus spelaeus*) and in which the cultural remains of *Homo sapiens* have so far never been found.

Adhering to the right wall, along the fault which caused the formation of the cave, partially inside the mouth and covered by Levels 1 and 2, was a deposit of travertine. This deposit, white and porous, was due to one of two causes: infiltration of water down the face of the fault or a blocking of a stream once flowing out of the cave at this level.[8] There are three phases in its formation: the oldest, at the bottom, is compact and sterile; the second, relic-bearing and grayish, with charcoal; the third and uppermost, sterile and friable. The flint and bone extracted from the relic-bearing level have a water-rolled appearance. Flint is extremely rare as, owing to the chemical action of the deposit it had so disintegrated as to be indistinguishable from the travertine. The bone presented the usual features of splintered bone coming from Paleolithic levels.

The relic-bearing level (pl. 1, Level 2) contained two small hearths. That found in the sounding proved to be but a vestige, yielding nothing but a small collection of flint and bone tools typical of the Aurignacian culture. A second hearth, slightly outside the cave entrance, was located at plus 20 centimeters and sloped out and upward to plus 60 centimeters. It was thin and reddish in color and yielded only a few flint flakes and splinters of bone. Although there were no other hearths in this level, a sufficient quantity of splintered bone and artifacts was recovered to show that it composed the terrace of Paleolithic times, while the artifacts themselves have distinct Aurignacian affinities. Only four of these objects are worthy of note: Two scrapers, one of rock crystal (pl. 2), and the other a fragment of bivalve shell much used and too small for identification of species; a shell of the species *Capulus hungaricus* Linné, perforated for suspension and having the inner surface of its lip decorated with incisions; and an unusually large conch of the species *Triton nodiferum* Lamarck encountered at plus 1.60 centimeters (pl. 3). This mollusk, belonging to a warm-water fauna, occurs in the Atlantic as far north as the Charante Inférieure and is rare in the Mediterranean. It inhabits the coral zone at 25 to 75 meters depth and is therefore seldom thrown up on the shore. The species averages 230 to 250 millimeters long, sometimes reaching a length of 300 millimeters, while the width averages 170 millimeters. The Marsoulas specimen measures 310 by 180 millimeters. It had remained on a beach for a considerable length of time, as the test shows attack by *Algae clione*. The cone of the shell had broken and healed during its lifetime. Except for an ancient

[8] *Idem*, p. 1, footnote 1.

irregular breaking of the lip and an unfortunate perforation at the time of excavation, there is no artificial adaptation of any sort.[9]

The find of a *Triton* shell in a Paleolithic level is important from several points of view. A few stations have yielded *Strombus*, but this is the only *Triton* so far reported. The 250 kilometers separating Marsoulas from the Mediterranean and the 300 kilometers distance from the Atlantic is witness to the wide migrations or trade contacts of the Paleolithic hunters, provided the species existed in those seas during Quaternary times. If it did not, the distance over which it came indicates for these hunters travels or contacts farther afield than has been previously considered possible.

Fauna from the Paleolithic terrace: Red fox (*Vulpes* sp.), fox (*Vulpes* sp. or *Alopex* sp.), horse (*Equus* cf. *caballus*), reindeer (*Rangifer* cf. *tarandus*), bovid (*Bos* or *Bison* sp.), Mollusca (*Capulus hungaricus* Linné, *Triton nodiferum* Lamarck).

Fauna from Aurignacian hearth: Fox (*Vulpes* sp. or *Alopex* sp.), horse (*Equus* sp.), reindeer (*Rangifer* cf. *tarandus*), bovid (*Bos* or *Bison*).

Fauna from travertine: Horse (*Equus* sp.), bovid (*Bos* or *Bison* sp.).

TARTE

On the floor of the cave of Tarte,[10] situated in the same hillside and 500 meters west of Marsoulas but in the Commune of Cassagne, Haute Garonne, an interesting industry in poor quality quartzite, neglected by former searchers, was remarked. It was decided to make a sounding in the hope of finding an intact layer that would date these artifacts.

Two layers were found, one on the right just inside the entrance and the other on the extreme left of the terrace. Both contained the Aurignacian typical of Tarte, and both contained the quartzite industry.

The form of the quartzite artifacts was limited by the poor quality of the material, and no particular type is recognizable. Only one face of these artifacts was retouched, and they apparently served as choppers and crude scrapers (pl. 4, figs. 1 to 4). The specimen shown in Plate 4, Figure 4, is water-worn and is, therefore, probably

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[9] The Smithsonian Institution wishes to express its thanks to Monsieur Joleau, Professor of Geology at the Sorbonne, who examined the specimen in question and gave the above opinion.

[10] Cartailhac, Quelques faits Nouveaux du Prehistoirie Ancien des Pyrenées. L'Anthropologie, 1896, p. 316; Cartailhac and J. Bouysonie, Une Fouille à Tarte. Assoc. Française Advanc. Sci., 1909, p. 128; Cazedessus, Jean, La Grotte du Tarte. IX Congr. de l'Union Hist. et Archaeol. des Societés du Sud Ouest, 1926.

of Lower or Middle Paleolithic age, having been found by the Aurignacians in a stream bed, brought by them to Tarte and used without further adaptation.

Among the quartzite pieces on the floor of the cave was found a splendid example of the Paleolithic artist's pallette, which probably came from the Aurignacian levels. This piece consists of the cleanly broken half of a quartzite pebble, the flat surface of which is thickly coated in red ochre. It measures 23 centimeters long by 19 centimeters wide.

THE OPEN-AIR WORKSHOP OF ROQUECOURBERE

Four kilometers "as the crow flies" due east from Marsoulas and Tarte is a cave known as the Cave of Roquecourbere[11] situated in the Commune of Betchat, Ariège. It is one of the two sites in the Pyrenees that yielded remains of the Solutrean culture. Soundings were made here, but it was found to have been completely emptied. Below the cliff containing this cave, on the left bank of the little stream known as the Lens, is the open-air workshop of Roquecourbere.

The site is in a wood and covers several hectares. A number of man-made flint flakes found in a rain-washed cart track leading through it first attracted attention to the station.

Twenty-one soundings were made. Below a level of humus varying from 60 centimeters to over a meter in thickness was a layer 50 centimeters thick consisting of quartzite pebbles and flint nodules of poor quality tightly packed with earth. This layer had been superficially quarried from the surface in Upper Paleolithic times. Artifacts and débris of manufacture occurred in this level, as well as in the lower part of the humus. In sounding No. 8, a considerable quantity of flints was found where the quarry layer appeared to have been dug into deeper than elsewhere. The stones had been thrown aside so as to make a cup-like depression, whose borders were covered only by a few centimeters of humus.

The quality of the material is very poor and the yield of the station meager; the proportion of worked flakes and finished tools is only 10 to 15 per cent of the whole (pls. 5-8). Plate 6, Figure 1 shows a nucleus trimmed into a double scratcher resembling the rostro-carinate scratchers of the Aurignacian from Tarte.

The industry belongs to the Lower Aurignacian, but if the workshop was used by the people of Tarte, the poor quality of the material rendered impossible the production of typical Tarte pieces.

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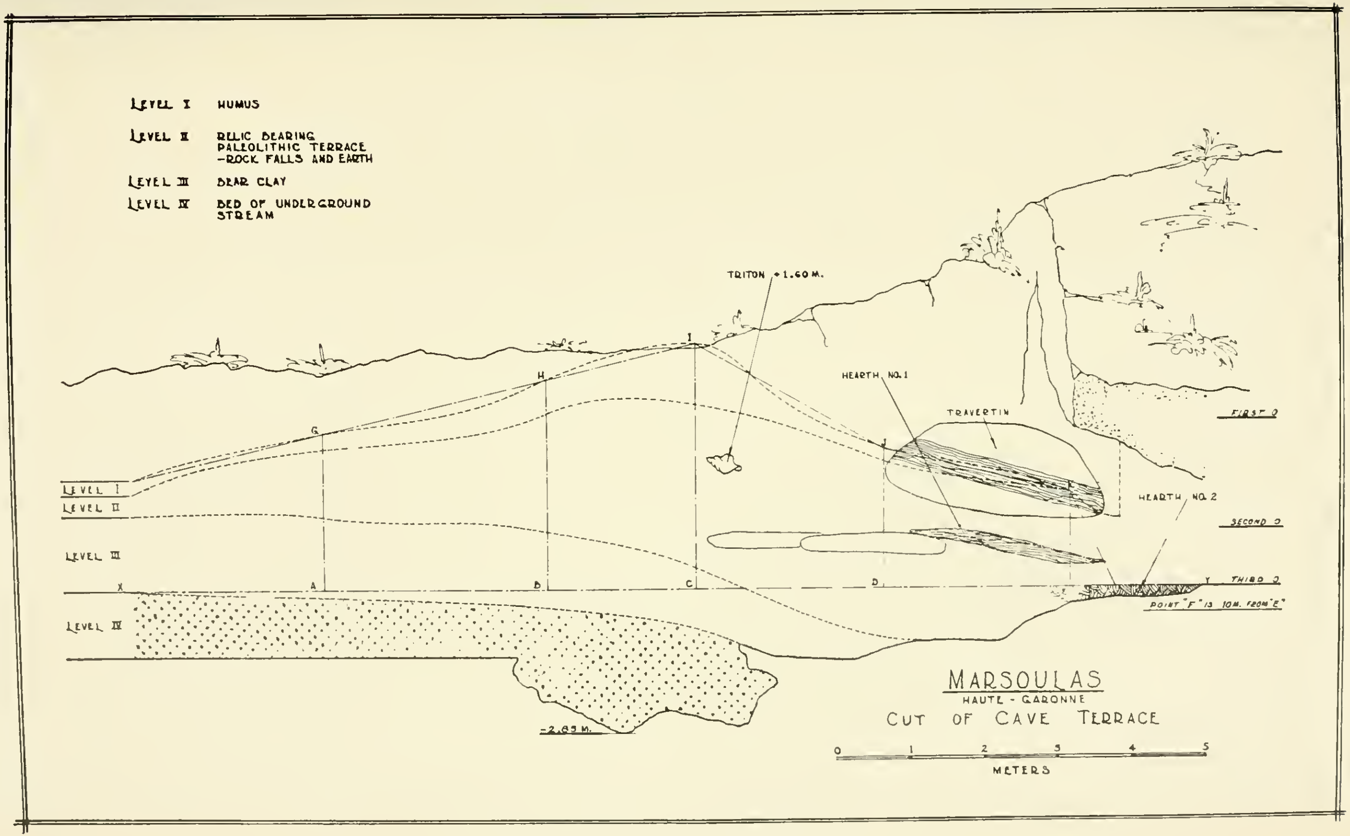
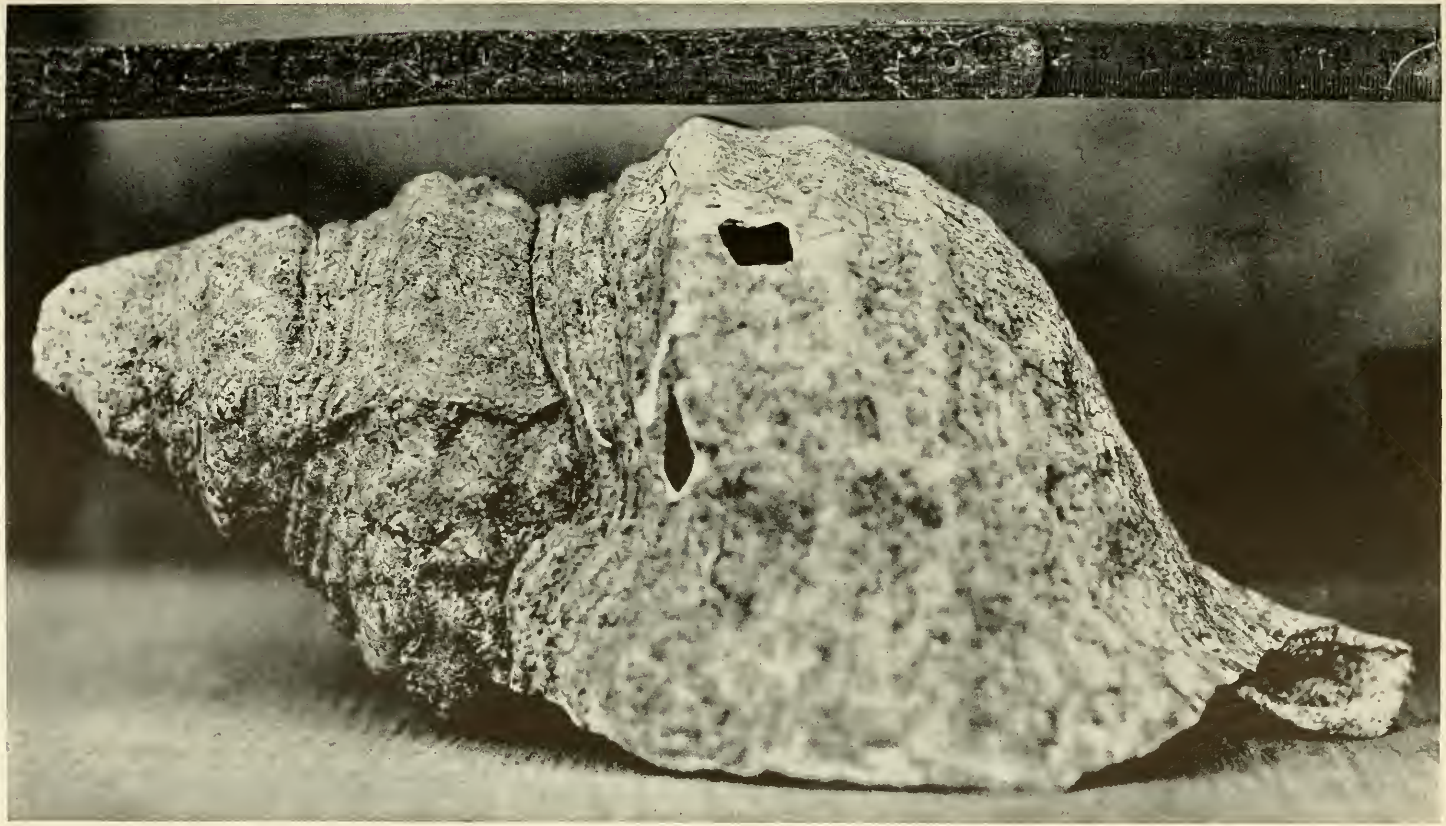
[11] Cazedessus, Jean, Galerie de Roquecourbere. Assoc. Française Advanc. Sci., Congr. du Havre, 1929.

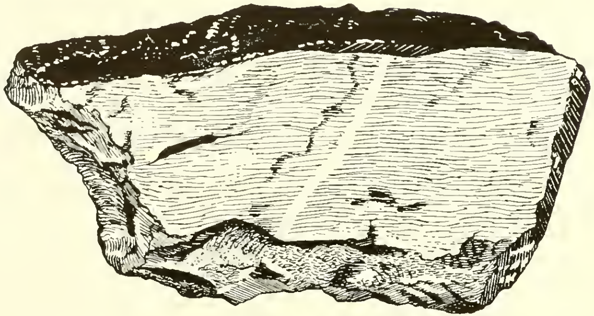


Cut of the terrace of Marsoulas.

Rock-crystal scraper, Level 2, Marsoulas.



Shell of *Triton nodiferum* Lamarck, Level 2, Marsoulas.



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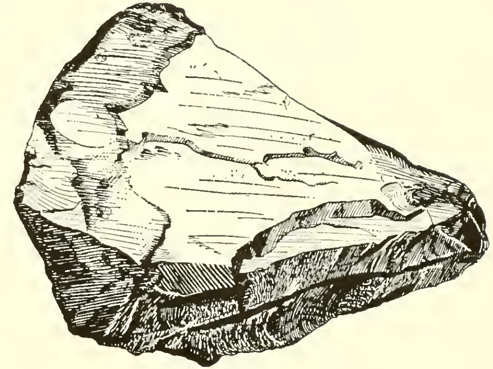

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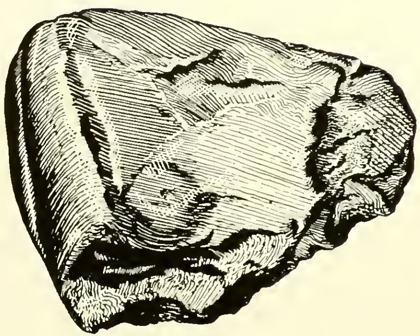

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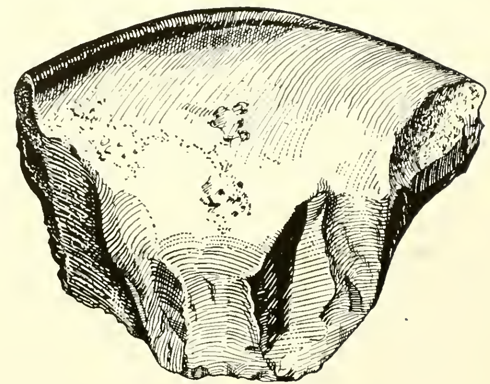

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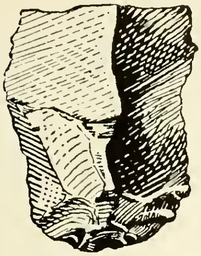
Four specimens of the quartzite industry, from Tarte.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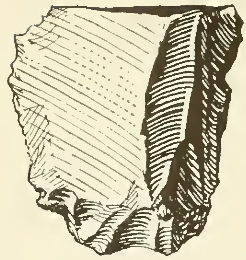
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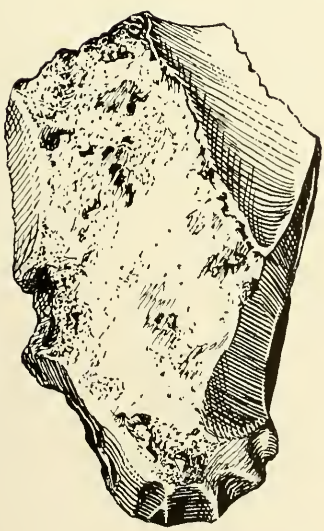
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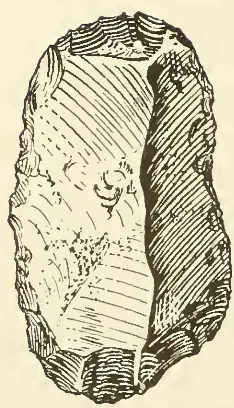
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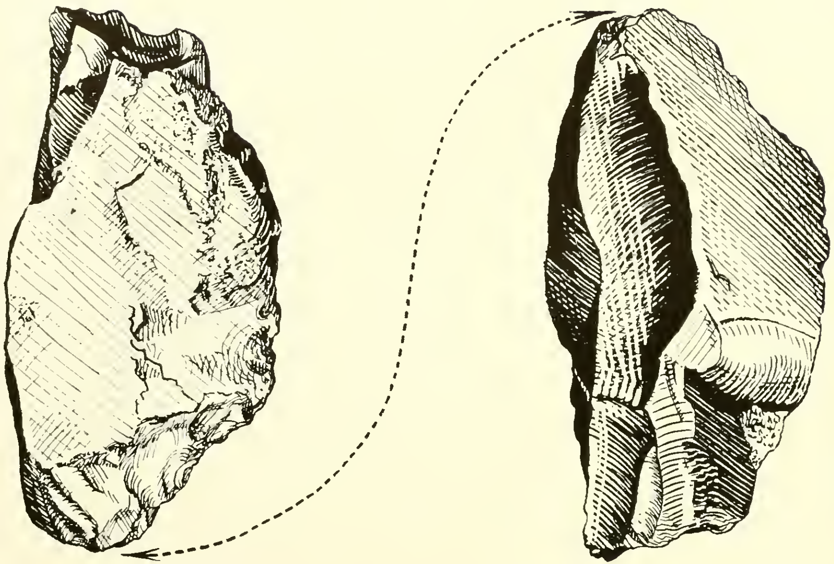
Five scratchers from the open-air workshop of Roquecourbere.



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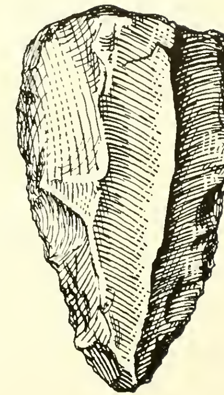

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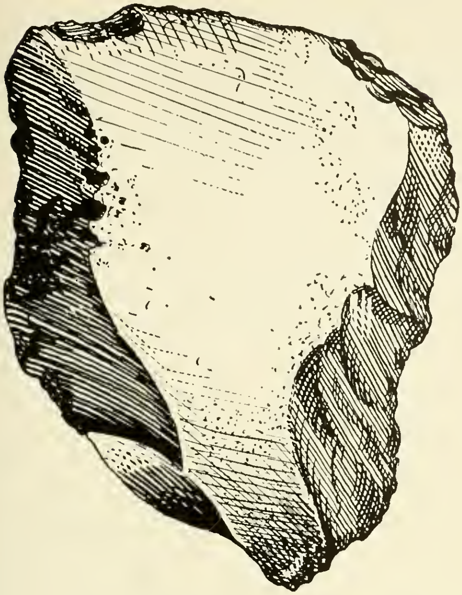
Artifacts from the open-air workshop of Roquecourbere.

1, Nucleus trimmed into a double scratcher; 2, point.



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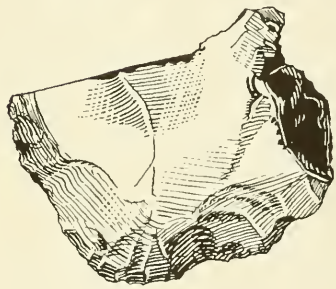

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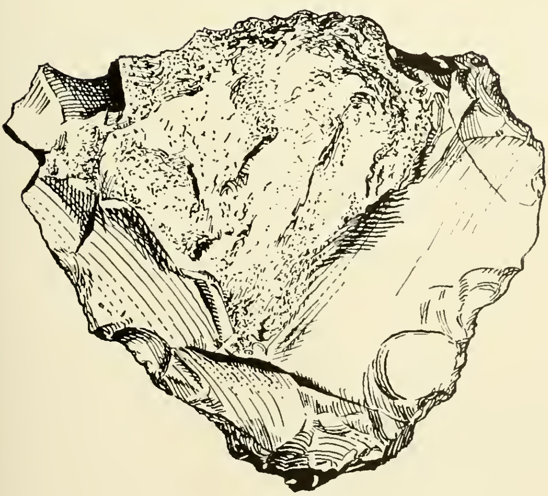

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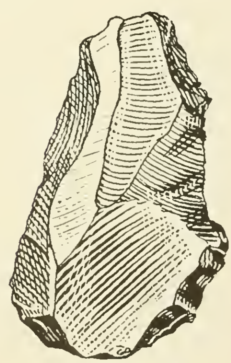

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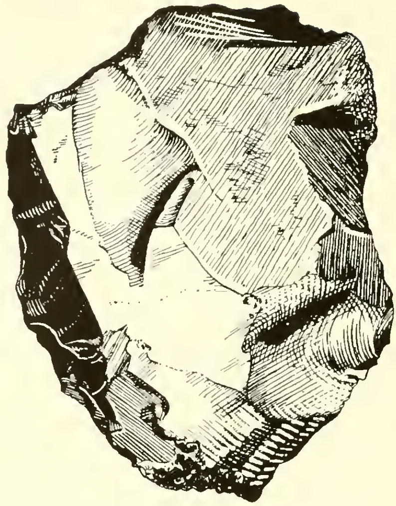
Five scrapers from the open-air workshop of Roquecourbere.



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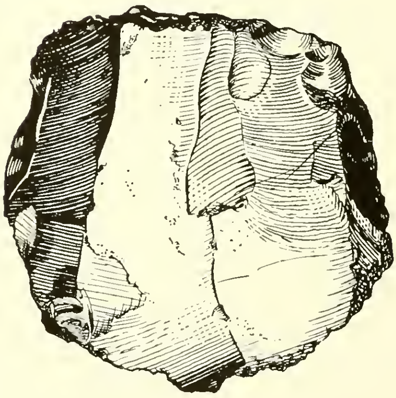

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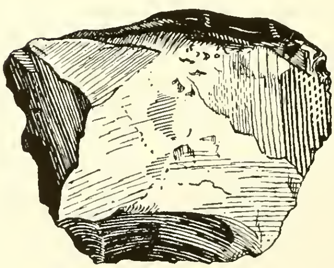

3

Three nucleii from the open-air workshop of Roquecourbere.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 87, NUMBER 12

A SPECTROPHOTOMETRIC DEVELOPMENT FOR BIOLOGICAL AND PHOTOCHEMICAL INVESTIGATIONS

(WITH THREE PLATES)

BY
F. S. BRACKETT AND E. D. McALISTER
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(PUBLICATION 3176)

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Investigations of the effect of radiation upon biological material can be carried out advantageously with microscopic organisms such as unicellular algae, bacteria, yeast, and fungi, along lines closely analogous to customary spectroscopic practice. The great advantage of this general method of approach is that one is able to obtain numerical evaluations which depend statistically on large numbers of organisms without going to equipment of cumbersome dimensions. The needs are, however, sufficiently different as to make desirable the development of special equipment and methods. It is our purpose to describe the development along these lines which has been undertaken in the Division of Radiation and Organisms, with a view to carrying out cooperative investigations with biologists who have specialized in the study of particular types of small organisms. It has been our idea to make the special equipment developed available not only to members of the Division but more generally to biologists who may arrange to carry on investigations at the Smithsonian Institution in cooperation with the Division.

The first of these cooperative experiments has been carried out with Dr. Florence E. Meier, National Research Fellow, working with the alga *Chlorella vulgaris* of her collection. The results of her experiments have been presented in a previous publication, Smithsonian Miscellaneous Collections, Vol. 87, No. 10, 1932. Some of the problems of a physical nature which have arisen in the course of these experiments will be taken up in connection with this discussion.

In order that advantage may be gained from comparative observations of a differential type it is desirable that the organisms be exposed to several wave lengths at the same time. Where slides can be prepared coated with a layer of microscopic organisms, they may be exposed in an instrument of the spectrograph type. Since, however, there exist essential difficulties in securing either as great uniformity or as fine texture or structure as is presented by the photographic plate, it is desirable to secure as large an area exposed to a given wave length as possible. In other words, one wishes to work with a wide and long slit and as large monochromatic images of the slit as is compatible with essential spectral purity. A second demand is that provision be made for a nonselective determination of the relative intensities of the different wave lengths incident upon the organisms. A third demand is that provision be made for the exposure of the organisms without great hazard of contamination.

These three requirements determine the general character of the combined recording monochromator and biological spectrograph which has been constructed. Since one of the most interesting regions from a biological standpoint lies between 2,500 A. and 3,000 A., fused quartz serves very well as the material for the construction of the optical parts. The difficulty which such material presents due to its slight inhomogeneity is not of great moment in this connection. The resulting loss of definition is of no consequence because of the wide slits demanded by the coarse-structured biological plates. In order that a comparatively high degree of spectral purity might be maintained despite the use of large slit-widths, a relatively great dispersion is required. This is obtained by the use of two 60° prisms, together with focal lengths of collimator and telescope of 50-60 cm. In order to maintain a high light intensity, unusually large prisms have been employed, yielding a numerical aperture of f. 4 to f. 5 depending on the wave length. The second prism is slightly larger than the first, the first being 13 cm high x 13 cm diagonal face, the second 14 cm high x 16.5 cm diagonal face. The use of a larger second prism minimizes the reduction in aperture for the beams of least and greatest deviation. The optical arrangement is shown diagrammatically in Figure 1. With the high numerical aperture, it was necessary to have the lenses ground aspherically in order to minimize spherical aberration. Since it was desirable that the instrument should be used efficiently over a wide range of wave lengths either as a spectrograph or monochromator, provision was made to swing both collimator and camera. The first slit " s " is curved, compensating for the change of prismatic deviation off the axis and thus yielding straight line images of the slit. A slit-length as great as 5 cm proves to give satisfactory images. Provision is made for the independent focusing of both collimator and camera. The lenses are 16.5 cm in diameter. The camera has been specially constructed to serve first, with a conventional plate holder, for photographic purposes, and second, with a special plate holder which can be sterilized in an autoclave, for biological purposes. This plate holder is constructed of metal and provided with both shutter and quartz window so as to isolate the biological material under sterile conditions. Furthermore, provision is made to traverse the spectrum with a thermocouple. This is supported by a worm-driven dovetail slide. Last, a second slit may be supported in place of the thermocouple and the instrument used strictly as a monochromator. Provision has been made for automatically recording the galvanometer deflections when the spectrum is traversed by the thermo-

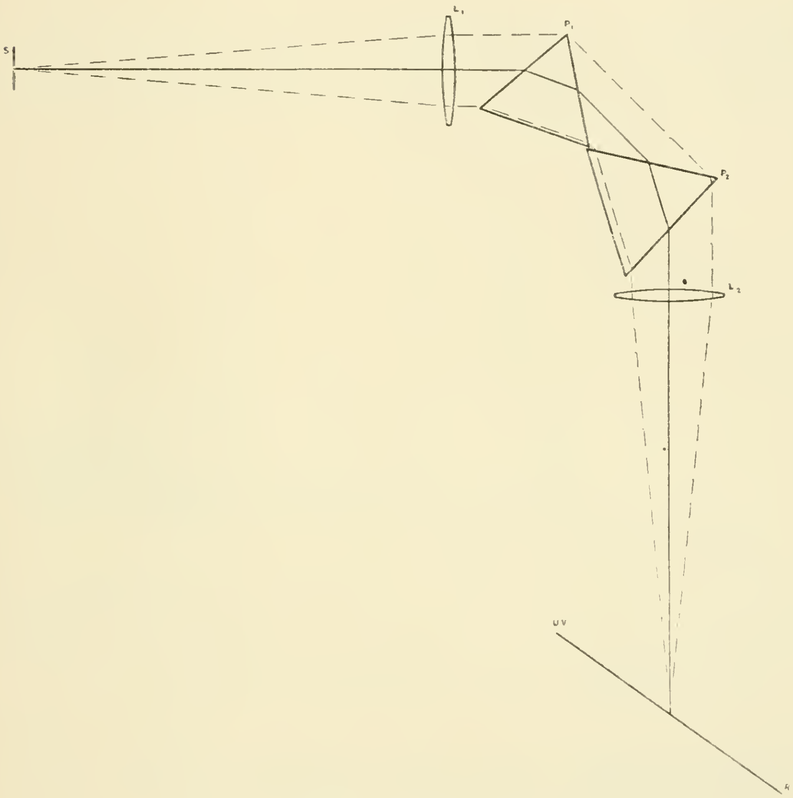


FIG. 1.—Diagram of optical arrangement.

couple. The instrument is provided with scales and is of such rigid construction as to make possible a high reproducibility of setting.

Plate 1 shows the spectrograph with the prisms exposed. A number of unique features will be noted; the extra long slit is supported by parallel rods which extend so as to carry the source and the condenser lenses when used. This permits the swinging of the collimator without realignment of the preliminary system. As will be noted, the instrument extends from one room to another. Provision is made for closing the window, thereby isolating the working room from the source of ultra-violet light. The standard plate holder mounting is shown at the left while the special biological plate holder lies at the front of the concrete table. It is shown with the back removed. Slide and quartz window are placed at 45° to the plate support in order to minimize reflection from the window.

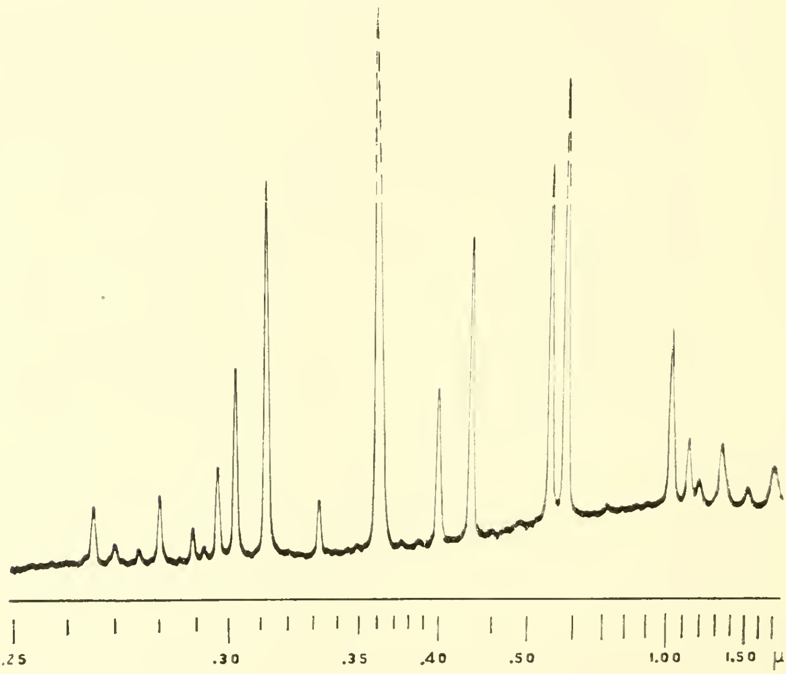


FIG. 2.—Record of mercury spectrum taken with open thermocouple.

Plate 2 shows the camera, thermocouple, and recording system in the adjoining room. The biological plate holder is in place with the back and slide removed. The thermocouple can be moved across the spectrum under these conditions, the traverse thus being made under the identical conditions to which the biological material is exposed. At the extreme right the box is shown which houses a cylinder upon which the galvanometer record is made through a cylindrical lens. Gear mechanisms accomplish convenient reduction of motion so as to secure the desired spread of spectrum upon the record. An interchange of standard reduction gears allows a modification of ratio.

Figure 2 is a direct record of the mercury spectrum from 2,500 A. to 1.7μ. This record was made with an open thermocouple, thus avoiding the difficulty of correcting for window transmission. Only two settings of collimator and camera have been required for the recording of the entire range of the spectrum, the region from 2,500 A. to 3,900 A. being traversed at one setting and the region from 3,900 A. to 1.7μ at the other. In this case a small spread or high gear ratio has been used in recording to show conveniently the entire spectrum.

Figure 3 is another automatic record of the mercury arc taken with a vacuum thermocouple of the type described by Brackett and McAlister.[1] As will be seen this record has been taken with a finer slit-width, the spectral range subtended by the slit being of the order of

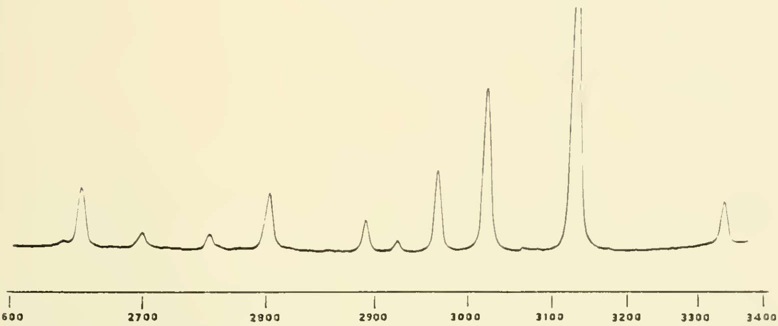


FIG. 3.—Record of mercury spectrum taken with vacuum thermocouple showing higher resolution and greater stability.

8 A. Here a lower gear ratio has been used in order to secure a larger spread. This permits the ready integration of areas for quantitative comparisons. One will note that the same order of deflection has been achieved despite the great increase in resolution and improvement in stability of zero.

Plate 3, Figure 1, shows a photographic spectrogram of the quartz mercury arc. Although rather a wide slit has been used it will be seen that the finer lines are sharply defined. Furthermore, although over 4 cm of slit-length has been shown in the illustration excellent straightness of line has been obtained.

Plate 3, Figure 2, shows a typical spectrogram obtained with biological material where the organisms are destroyed by the wave lengths of a given spectral region. This was obtained by Doctor Meier, using unicellular algae, and was discussed in her paper " The Lethal Action

[1] The automatic recording of the infra-red at high resolution. Rev. Sci. Instruments, vol. 1, no. 3, pp. 181-193, 1930.

of Ultra-Violet Light on a Unicellular Green Alga."[1] As will be noted in comparing Plate 3, Figures 1 and 2, lines in the region from 2,500 A. to 3,000 A. appear in much their usual character, while the very heavy lines shown between 3,000 A. and 3,200 A. are wholly lacking. In order that such a biological spectrogram may be made to yield a quantitative measure of lethal effect, one may resort to the microphotometer methods which are in use for photographic purposes. Again, the only essential difference is that one is dealing with a plate of less uniformity and greater coarseness of structure in the biological work. Consequently, a recording microphotometer of the

Fig. 4.—Photometric record of algal spectrogram of mercury arc.

Moll type may be used, provided it is equipped with unusually long and wide slits, thus providing an integration over a considerable area.

Figure 4 shows such a record by the microphotometer of the algal plate. The lines are readily recognized although it will be observed that the heavier ones have been so overexposed as to present a flat-topped or truncated appearance. Such a thin plate effect may be partially corrected by extrapolating the curves to a normal pyramidal shape. This is, of course, only a first approximation, accurate work requiring varied exposures so that one stays within a narrow range of effective lethal action.

Figure 5 shows a similar record by the microphotometer of the photographic spectrogram, Plate 3, Figure 2. Although there is in this case no evidence of a thin plate effect, the fact that the sensitivity of the plate varies widely, not only for different wave lengths but also for different intensities, is readily observed by a comparison of this record with Figure 3. For convenience, the microphotometer used has been equipped with extra large slits, special lenses being substituted for the microscopic type in standard use. Thermocouple and second lens have been eliminated, a Weston photronic cell being sub-

[1] Smithsonian Misc. Coll., vol. 87, no. 10, 1932.

stituted for this work. Because of its large area and uniform response this arrangement proves quite satisfactory. It is, of course, particularly suitable to the algal plate. As the same set-up of the photometer was used with the photographic plate, considerable of the detail is not brought out.

This combination of equipment, spectrograph and microphotometer, makes possible a type of biological investigation which is capable of yielding quantitative results, approaching those of photographic spectrophotometry, the limit being set simply by the uniformity of texture of the biological plates which can be prepared.

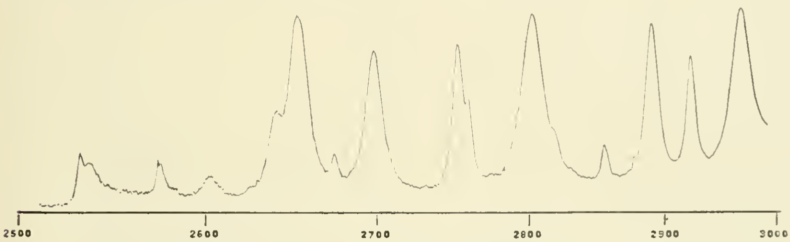
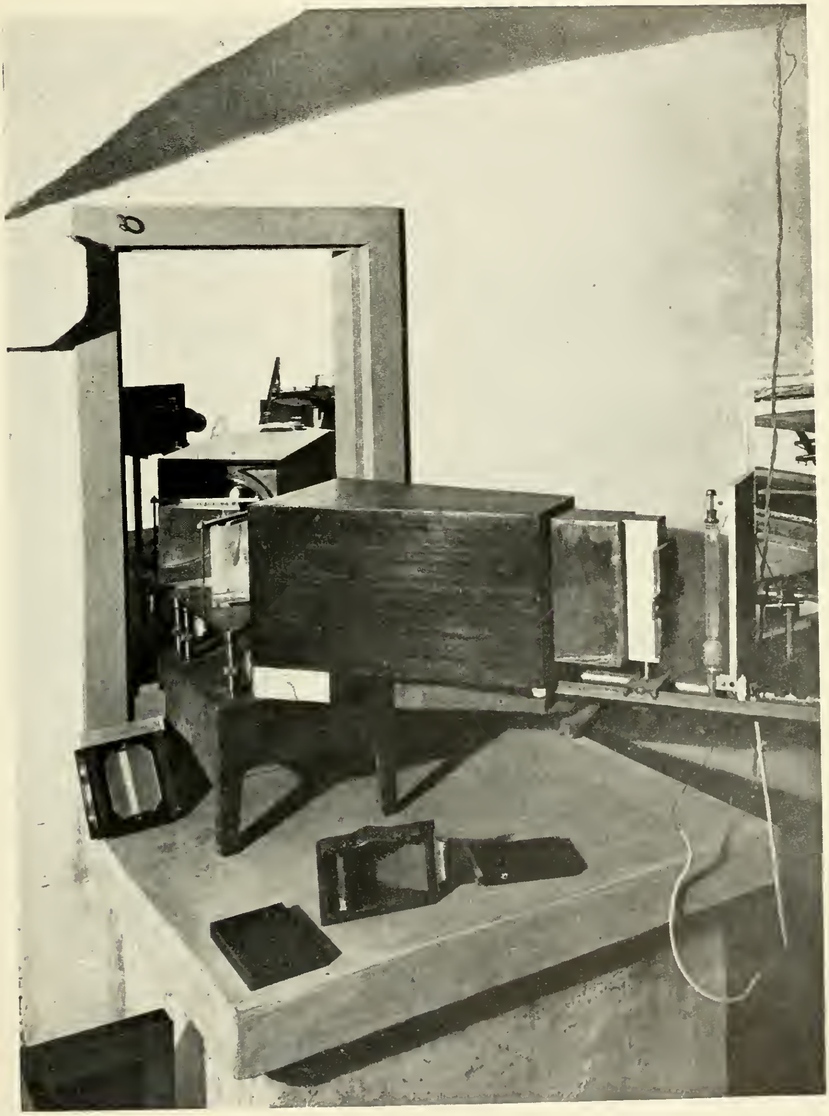
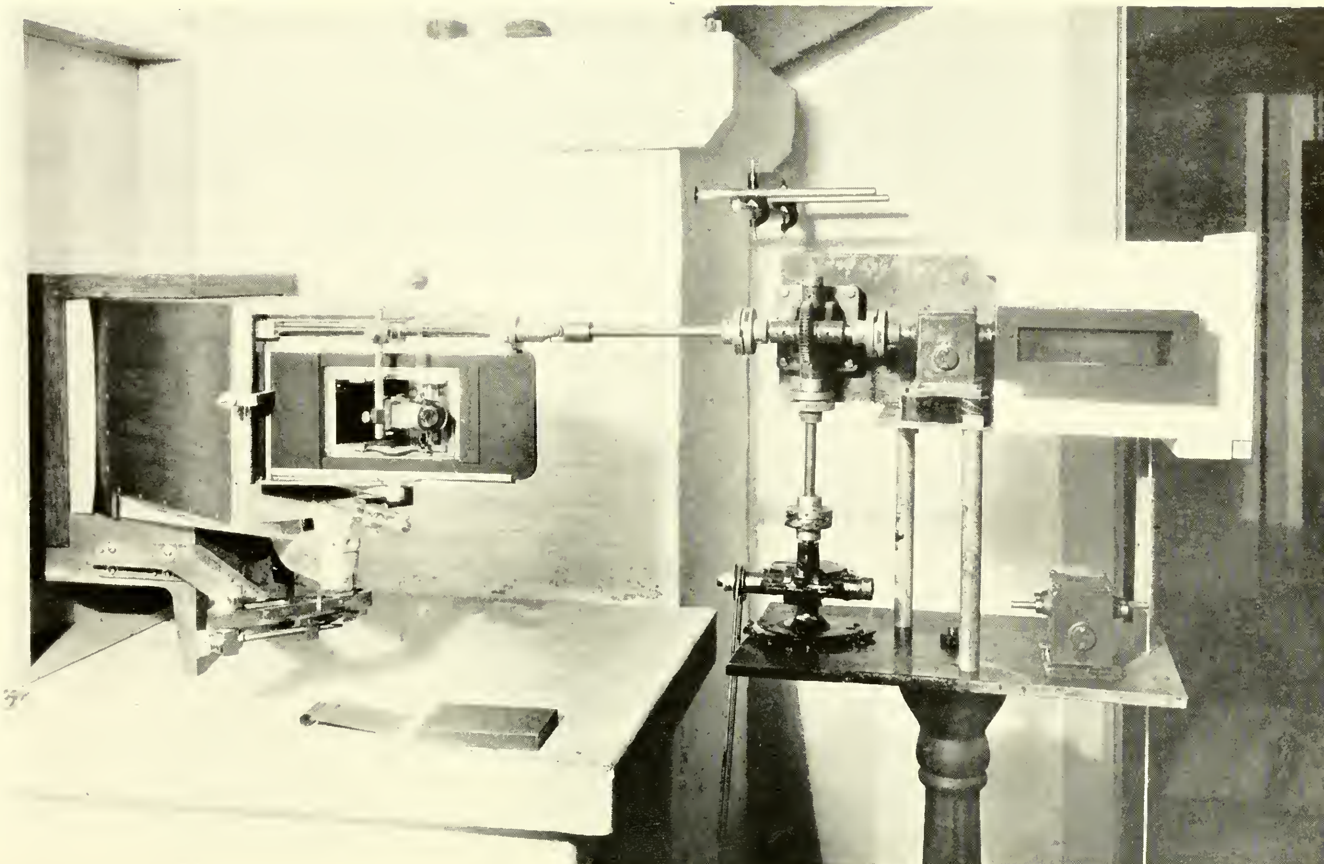


FIG. 5.—Photometric record of photographic spectrogram of mercury arc.

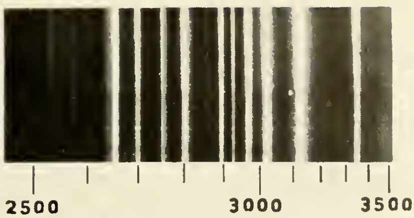
Obviously the equipment developed presents unusual advantages for pure photochemical investigation. Because of the large aperture and long slit it is possible to secure a large amount of monochromatic energy, thus enabling one to work with large enough quantities of material for convenient analysis. A mounting has been developed which permits the simultaneous exposure of 6 small test tubes to different lines of the spectrum. As in many cases slit-widths as great at 2 mm are possible without overlapping of lines, amounts of energy become available of the order commonly secured in photochemical practice by technique which yields considerably less resolution. Thus, with lines varying in intensity from 4.8/ergs/sec./mm^2 to 125.6 ergs/sec./mm^2, and slit 2 mm wide by 50 mm long, one obtains corresponding rates of energy supply 480 ergs per sec. to 12,560 ergs per sec. Each test tube is surrounded by its own cylindrical cover in which a slit of the desired width has been cut. This second use of the instrument has already proved of considerable interest, cooperative work having been carried out with the United States Department of Agriculture upon photochemical changes in plant products.



Spectrograph for biological and photochemical investigations.

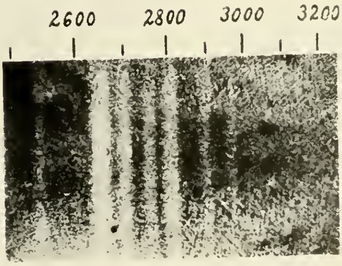


Camera of spectrograph showing mechanism for moving thermocouple and directly recording the spectrum.



1

Photographic spectrogram of mercury arc.



2

Spectrogram of mercury arc shown by lethal effect on algae.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 87, NUMBER 13

THE FUNCTIONS OF RADIATION IN THE PHYSIOLOGY OF PLANTS

I. GENERAL METHODS AND APPARATUS

(WITH ONE PLATE)

BY
F. S. BRACKETT AND EARL S. JOHNSTON
Division of Radiation and Organisms, Smithsonian Institution

(PUBLICATION 3179)

CITY OF WASHINGTON
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[With One Plate]

Radiation undoubtedly affects many of the physiological processes of plants in addition to the well-recognized ones of photosynthesis and phototropism. To what extent these and other reactions may influence each other, if at all, is wholly an open question. Since it has been impossible to produce artificially any process which bears a close similarity to those found in the plant, one must perforce seek as complete data as can be obtained from direct studies of plant behavior. Modifications of the two essential light characteristics, wave length and intensity, may in general affect not only the reaction which is being given particular attention, but also other photochemical reactions which take place in the plant. So far as observational data are concerned one is limited to numbers which represent overall effects, that is, gas interchange, change in dry weight, change in height, change in shape, change in color, etc. Anyone who assumes that one of these overall numbers may be varied without influencing another must certainly accept the burden of the proof.

Consequently it is our view that investigations of photosynthesis cannot safely be interpreted without due consideration of problems of growth and characteristic plant behavior. It has therefore been our purpose to supplement our investigations of photosynthesis with experiments to determine the ways in which changes in intensity and wave length affect the characteristics of plant behavior. In order that such investigations of the light variables may yield data which are reproducible and significant, it is of course necessary that other variables be maintained constant and as far as possible defined as to magnitude. Obvious as such a consideration is, failure sufficiently to realize this demand has contributed to a considerable degree to the chaotic results found scattered through the literature. However, to create conditions under which the physical and chemical factors of environment can be sufficiently well controlled and defined is by no means a simple problem.

The Division of Radiation and Organisms of the Smithsonian Institution has devoted considerable time and effort during its first three years to the development of equipment and methods for the comparative investigation of the effects of light upon plant growth and behavior. Since to a considerable degree the general plan of investigation and the apparatus employed will be common to a series of experiments it seems desirable to describe the developments in some detail. Such is the purpose of this discussion.

SOURCES OF RADIATION

The type of set-up to be developed depends necessarily in a large measure upon the characteristics of the sources of radiation which are available. Practically one has three choices: first, the sun; second, standardized incandescent filament lamps; third, electrical discharges through gases. The chief objection to the first, namely, its unavoidable fluctuation in intensity and distribution, has been sufficient to rule it out in the present undertaking. In designing the apparatus provision has been made to utilize both of the latter types. Incandescent lamps have the definite advantage of furnishing radiation distributed continuously over a large range of wave lengths. They can be obtained with a minimum of expense and, with suitable control, made to yield reasonably constant conditions. If it is desired, however, to restrict the light to a very narrow wave-length range, that is, pure color, one finds rather rigidly-defined limitations. A monochromator type of illumination must be ruled out in the case of most investigations of higher plants, not only because of expense but also because it fails to furnish a sufficient quantity of available radiation. The use of light filters, however, enables one to modify and limit the distribution to a considerable extent.

An interesting set of filters, developed by the Corning Glass Works, transmit continuously the radiation of long wave lengths from about 2.5μ in the infra-red to fairly well-defined limits in the visible and ultra-violet. This short wave-length limit differs for the different filters. A group of 10 filters may be chosen, for which the short wave-length limit varies at convenient intervals from the deep red to the ultra-violet beyond 2,900 A. While the short wave-length limit is not ideal, the change of transmission from 80 per cent or more to less than 2 or 3 per cent takes place within a few hundred Angstroms. The transmission characteristics of these filters are shown in Figure 1, curves 1 to 10. Percentage transmission is plotted against wave length in microns. The infra-red transmission values have been determined upon an automatically recording infra-red spectrograph constructed at the Fixed Nitrogen Research Laboratory in cooperation with this Division. For the visible and ultra-violet they have been determined by means of a double monochromator using the special thermocouples developed in this Division. Two standard Bausch & Lomb quartz monochromators have been combined in order to secure greater wave-length purity. These observations will be discussed in greater detail in other publications.

From a photochemical point of view this set of filters has a number of interesting possibilities. Since photochemical reactions show a long wave-length threshold, that is they do not proceed for any wave lengths longer than a definite value (the threshold), it is possible with such a group of filters to vary the illumination so that different photo-

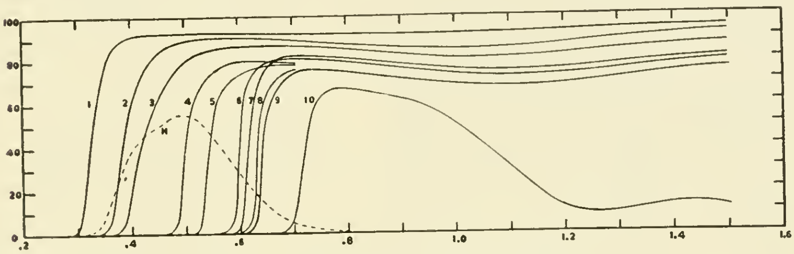


FIG. 1.—Transmission curves of filters.

1, Pyrex; 2, Nultra; 3, Noviol, shade O; 4, Noviol, shade C; 5, Heat resisting yellow, yellow shade; 6, Lighthouse red; 7, Heat resisting red, 212 per cent; 8, Heat resisting red, 122 per cent; 9, Heat resisting red, 62 per cent; 10, Blue purple ultra plus heat resisting red, 212 per cent; H, Heat absorbing Alko, light shade.

chemical reactions may be differently affected, provided they have different long wave-length thresholds.

Another set of filters is also of interest in such experiments. This is a group of heat-absorbing filters which remove the infra-red longer than 1μ and cut off in varying amounts the near infra-red and longer wave lengths of visible radiation. Such filters are of particular importance in view of the fact that standard incandescent lights produce an excessive amount of infra-red radiation as compared to the sun. At present only one type of heat-absorbing filter has been obtained. The transmission of this filter is indicated by the dotted line H in Figure 1. Other filters which transmit a greater proportion of light in the red are being procured. These glass filters have the advantage of a considerable degree of permanency.

Only a few filters are available that eliminate both the long and short wave-length ranges of the spectrum, leaving a definite band of limited wave-length range in the transmitted beam. Unfortunately the few filters which are available either transmit too wide a band for significant experimentation or transmit too low an intensity for practical purposes. Consequently lamps of the incandescent type together with available filters fail to meet a very urgent need for practically monochromatic sources of illumination.

This need is met by the last mentioned group, namely, electrical discharge through gases. Such sources of illumination have been in common laboratory use for physical investigation for decades. Commercial application however, until very recently has been limited to the mercury arcs. The development of Neon signs has stimulated industrial interest in such sources of light which emit selectively a limited number of practically monochromatic " lines " of radiation. Helium tubes are now available which furnish an intense yellow radiation and sodium tubes have been developed and should be available in the relatively near future. Hydrogen tubes are a matter of common laboratory practice. These yield a very strong red line together with less intense blue-green and blue lines.

In order that these sources may be used intelligently it is necessary that the distribution of energy of a given source maintained under specified conditions be known. While data are available so far as the common incandescent light is concerned, such is by no means the case in regard to the sources of selective emission, namely, discharges through gases. In order to meet this situation our laboratory has been equipped not only to make such special lamps as are not available, but also to make photometric determinations of the distribution of intensity in terms of well-defined standards for all types of sources. Since information is required for the entire range from 1.5μ to $.2\mu$, both as to emission of sources and transmission of windows, the spectroscopic developments are rather unusual in scope. Automatically recording instruments are being developed which will yield absolute intensities for the entire range. Results of these developments will be discussed in other papers.

PLANT GROWTH CHAMBERS

With the general attributes of available sources of radiation in mind, a set of growth chambers has been developed whose primary purpose is to expose plants to different radiation conditions while other factors of environment are maintained essentially the same. In order that temperature, humidity, and gas concentrations may be as nearly identical as possible, the set of four chambers is controlled by a central reservoir and manifolding system. Both air and water are distributed from common sources, for the sake of temperature control. By the use of the same nutrient solution throughout an entire experiment, the nutritional factors are necessarily identical.

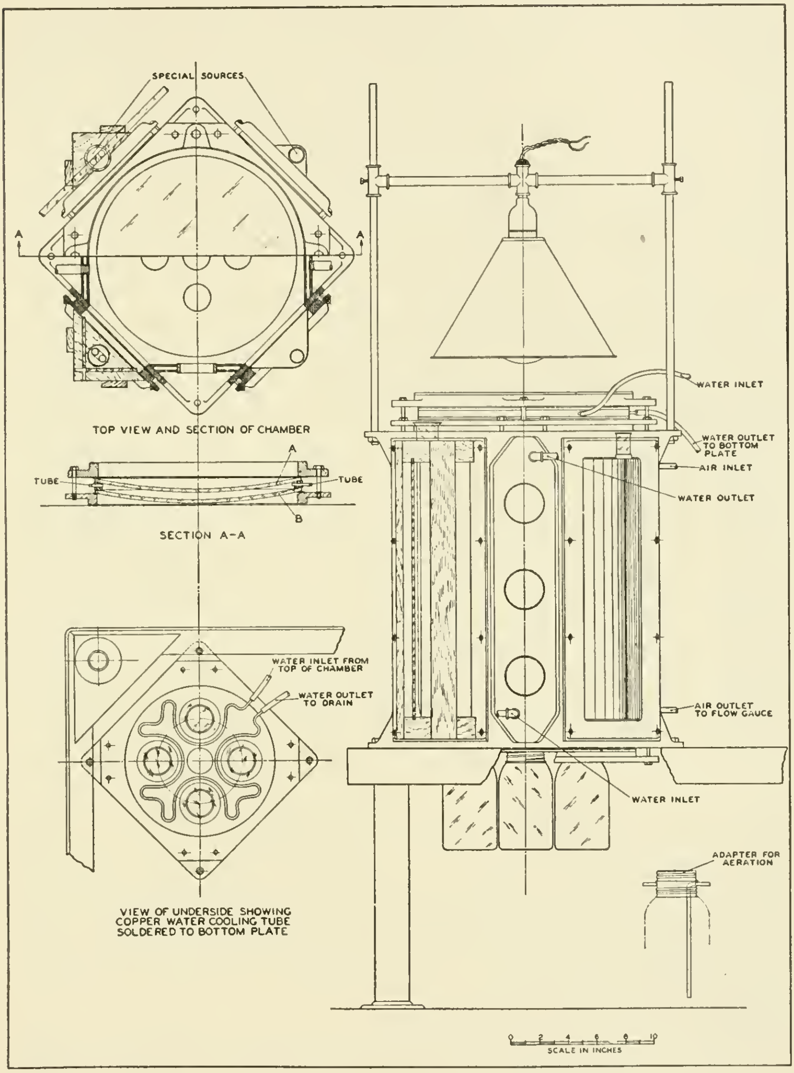


FIG. 2.—Detailed diagram of plant growth chamber.

Plate 1 shows the completed apparatus. The four growth chambers are located in the corner spaces upon a large steel frame. The center space accommodates the central controlling reservoirs. Each chamber is an octagonal cylinder in form, 22 inches high by 15 inches in diameter. The details of construction are shown in Figure 2. In order that the various types of light sources may be conveniently used and a maximum of flexibility obtained, arrangements have been made for both lateral and overhead illumination. Four of the eight faces of the octagon may be covered with glass windows, bolted on with suitable gaskets. The other four sides are double-walled in order to provide for temperature control by circulating water. These are shown cross-hatched, in a portion of the top view. The inner faces of these sides are of polished monel metal, which has the advantage of a fairly permanent polish and a minimum of variation of reflecting power from the visible to the far ultra-violet. Circular openings 14 inches in diameter have been provided in both the top and bottom. This choice of diameter enables one to use the standard front glasses of industrial flood lights for windows. These convex windows are available in pyrex, a matter of considerable importance when dealing with lights of high candle power. Furthermore, through the cooperation of the Corning Glass Works the filters previously described and usually available only in small sizes have been cast in these larger standard molds. It thus becomes possible to secure a color filter which will cover the entire opening. Provided with suitable gaskets two of these windows may be separated by a water layer, as shown in Figure 2, section A-A, thus providing for the removal of a large portion of the infra-red radiation and at the same time for the maintenance of the temperature of this top surface. The bottom opening is provided with suitable equipment for the introduction and support of the plants under observation. For convenience a metal disk may be bolted over this opening, which is provided with flanges threaded for the standard Mason jar. It has also been water-cooled for additional convenience in temperature control. This plate is shown in a bottom view in the lower left-hand corner of Figure 2. Since the frame upon which the chambers are supported stands some 18 inches above the floor these jars may be readily introduced from below and are supported from this plate by the threaded top. Thus water baths for temperature control of the roots can readily be introduced surrounding the jars.

Provision is also made for the introduction of an intermediate adaptor shown in the lower right-hand corner of the diagram, which permits air to be bubbled through the nutrient solution in the jars without escaping into the chamber above, the plants being supported in cork stoppers in the usual manner. Arrangement is made so that one large plant may be introduced into the chamber through a central opening, or four smaller plants symmetrically arranged and located opposite the reflecting walls as indicated by the diagram in the lower half of the top view. This arrangement provides that the central plant will be symmetrically illuminated from four sides, and where four smaller plants are used the distribution of radiation will not only be identical for the different individuals but practically balanced so far as lateral illumination is concerned.

In this plan the overhead opening is particularly convenient for the standard incandescent lamp. A suitable support which provides for the raising and lowering of the lamp and reflector is shown in the diagram. The lateral spaces, being long and narrow, lend themselves better to the discharge tube type of source. Where radiation in the regions of the ultra-violet is desired the use of ultra-violet transmitting windows presents such disadvantages, not only as to expense but also as to loss of radiant energy, that provision has been made to avoid them. In this case reflectors have been constructed which can be bolted on in place of the lateral windows, making the entire enclosure approximately a square with slightly rounded corners. In this case the ultra-violet sources of radiation are introduced through holes in the top, the only walls interposed being the transparent walls of the discharge tube itself and such cooling jackets as are required.

These special monel reflectors are shown on the right-hand side of the diagram, the ordinary window arrangement being shown on the left. In the latter case ordinary plate glass mirrors are inserted to form the corner. Of course, in actual practice all four windows are identically equipped, the diagram merely being a composite for convenience of illustration.

CENTRAL CONTROL SYSTEM

The central circulating system which has been developed for temperature and humidity control is shown in Figure 3. For convenience only one of the chambers is included. The location of the humidity-control tank has been changed in order to permit a clearer diagram of connections. The scale however is unchanged. A water-circulating system provides for identical wall temperature of the four chambers. From the lower central control tank thermostated to a temperature T^1, the water is pumped to the upper air temperature-control tank and thence downward to each of the four chambers, returning to the lower tank. Humidity control is secured by a similar recirculation of air. It is pumped through a copper spiral in the upper temperature-control tank T^1, thence through a central manifold into the various chambers. It emerges near the bottom of the tank through an air-flow meter, thence to a long spiral coil in the humidity-control tank at temperature T^2. Excess humidity produced by the transpiration of the plants condenses in this coil and may be removed from the con-

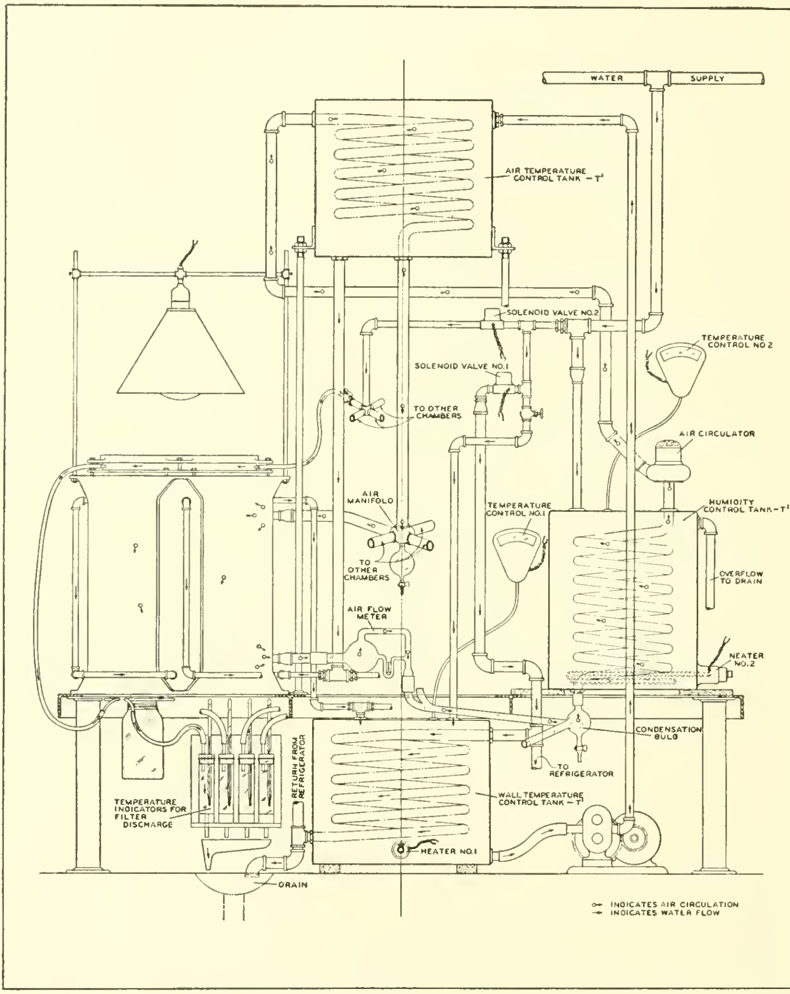


FIG. 3.—Detailed diagram of control systems.

densation bulb by a stopcock. As it passes through the spiral in the humidity-control tank the air is driven by a fan through the spiral in the upper control tank, where it is brought back to temperature T^1, and so returned by means of the manifold to the chambers. The proper humidity is of course maintained by suitable adjustment of temperature T^2 relative to T^1. Such new air as is required is bled into the circulating system from a compressed-air supply line.

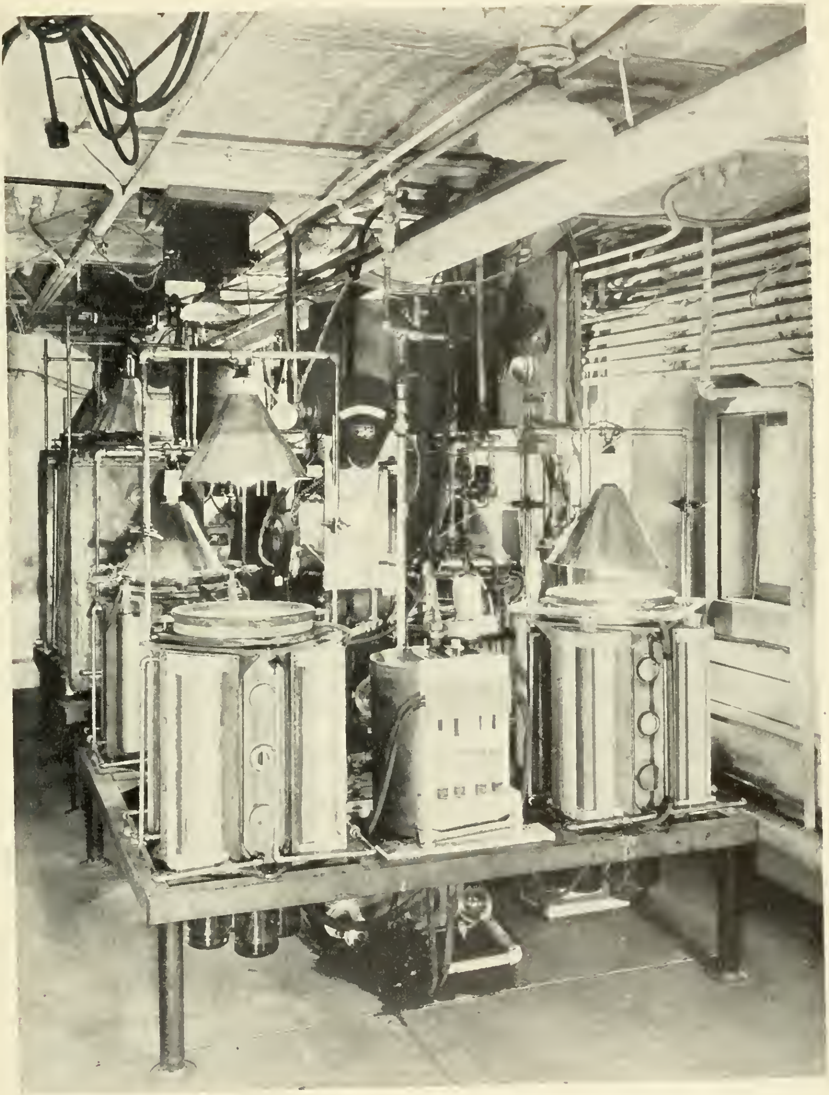
Since the water which is circulated into the walls determines the temperature of the air in the upper control tank, both water and air enter the tanks at the same temperature, T^1. As the four chambers may be illuminated by different intensities of radiation, the air may experience a different rising temperature in each chamber. In order to overcome this difficulty the water which is passed through the upper filter and also the lower plate, can be adjusted differently for the different chambers. The flow is adjusted and the temperature of the discharge observed as shown by the indicators in the lower left-hand corner. Since the upper filter and the lower plate are the surfaces which receive most of the overhead illumination this arrangement yields a very satisfactory control over the rise in temperature. As this compensating cooling is required only while the lights are on, a solenoid valve (No. 2) has been provided, which is connected to the lighting circuit so that the water is allowed to flow only when the lights are on. With the lights off, the side walls are still maintained at the same temperature by the main recirculation system. This insures that during periods of darkness the four chambers have the same temperature.

GENERAL

The chief advantage of the apparatus which has been described is that a satisfactory degree of control has been secured without loss of flexibility. It is readily adapted to all types of artificial light sources. Plants may be exposed to overhead or lateral illumination at will. Half of the entire solid angle may be utilized for illumination. Humidity can be controlled over a wide range. The temperature of three-fourths of the walls is controlled by water circulation. Gas concentration may be varied, as the entire enclosure can be hermetically sealed; the pressure of the gas phase may even be modified. Observations of growth and color may be readily made through convenient ports. Finally the apparatus lends itself readily to measurement of gas phase concentration, temperature, humidity, and light intensity. Measurements of carbon dioxide assimilation in connection with these various observations may be made under the influence of different spectral distributions, but at present this type of investigation is being carried out only in tubular glass growth chambers with young wheat plants.

In planning the apparatus the following types of experiments have been contemplated: 1, investigations of the effect of the infra-red;

2, comparative observations of visible radiation limited on the short wave-length side to different portions of the spectrum with a view to detecting the effects on photochemical reactions which differ as to threshold; 3, observations of the effects of monochromatic light in the visible and ultra-violet, first alone and second supplementary to other illumination.



GENERAL VIEW OF PLANT GROWTH CHAMBERS AND EQUIPMENT FOR CONTROL OF EXPERIMENTAL CONDITIONS

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 87, NUMBER 14

THE FUNCTIONS OF RADIATION IN THE PHYSIOLOGY OF PLANTS

II. SOME EFFECTS OF NEAR INFRA-RED RADIATION ON PLANTS

(With Four Plates)

BY
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Experimental results bearing on the influence of near infra-red radiation on plant growth and coloration are presented and discussed in this paper. Plants were grown under two different radiation distributions of equal visual intensity, one limited entirely to visible radiation, the other including a large amount of energy in the near infra-red. These preliminary experiments are a part of the program being undertaken by the Smithsonian Institution bearing upon the functions of radiation in various plant processes. A description of the special equipment (see pl. 1) that has been developed for the study of the effects of radiation upon plants grown under controlled conditions has been given in another publication (5).[1]

CULTURAL METHODS

The tomato plant was selected for these experiments because considerable work (12, 13, 14) had already been done with it in water culture and many of its growth characteristics are known. Furthermore, it has been used as an indicator plant (10) for determining the deficiency of certain fertilizer elements in the soil, and it responds very quickly to unfavorable atmospheric conditions. Because of its quick response to slight environmental changes its behavior is an excellent criterion of those conditions.

Tomato seeds of the Marglobe variety were germinated between layers of moist filter paper in a covered glass dish at a temperature of 25° C. When the roots had grown to a length of 2 to 10 mm the young plants were transferred to a germination net. This net was made by stretching two pieces of paraffined cotton fly-netting over a circular glass dish 19 cm in diameter by 10 cm deep. The

[1] Numbers in parentheses refer to the list of literature cited, found at the end of this paper.

two pieces of netting were separated by a piece of glass rod 0.5 cm thick, bent to fit inside the dish. As the roots grew through the mesh the two layers served to hold the plants in an upright position. Flowing tap water was passed through the dish in a manner to keep the upper layer of netting afloat. The plants were illuminated by a 200-watt Mazda lamp placed 30 cm above the netting. Lateral light was cut off by surrounding the germination net and plants with black cardboard tacked to a light wooden frame. This frame was raised above the table level and was large enough to provide ample air circulation around the plants. When the seedlings were approximately 3 cm in length they were transferred to the culture solutions. Each culture consisted of a single plant supported by means of cotton in a small hole in a paraffined flat cork stopper which fitted into a 2-quart Mason jar containing the nutrient solution. Four of these jars were then screwed to the under side of the bottom plate of each growth chamber; the young plants extended through the holes into the chamber.

The nutrient solution was made up of the following salts with the corresponding partial volume-molecular concentrations:

$Ca(NO_3)_2$	0.005
$Mg SO_4$	0.002
$K H_2PO_4$	0.002
$Mn SO_4$	0.0000178
H_3BO_3	0.00005

The approximate calculated concentrations of the nutrient ions in this solution expressed as parts per million and milliequivalents are:

	Ppm.	Milliequivalents [a]
Ca	200	10.0
Mg	49	4.0
K	78	2.0
NO_3	620	10.0
SO_4	194	4.0
PO_4	190	6.0
Mn	1	0.0364
B	0.55	0.15

[a] Calculations based on milliequivalent per liter $= \frac{\text{valence}}{\text{at. wt.}} \times$ ppm.

To this nutrient solution was added humic acid[2] containing 2.4 mg iron per cc at the rate of 0.5 cc per liter of nutrient solution. The

[2] The humic acid used in these experiments was supplied by Dr. Dean Burk of the Fixed Nitrogen Research Laboratory, United States Department of Agriculture.

method of making this iron compound has been described and discussed by Burk, Lineweaver, and Horner (6). This compound promises to be a very useful source of iron for nutrient solution experiments. Unlike most of the other iron compounds used in this type of work, the solution contains very little if any precipitate, even at high pH values. Hence it is not necessary to add this form of iron every day or two during the early stages of growth as must be done with ferric tartrate and some other iron compounds. One application of iron humate is sufficient to keep the plants green under good growing conditions for at least two weeks.

EXPERIMENTAL PROCEDURE

In the experiments herein described, only the overhead illumination was used. The light period for each 24 hours extended from 9 a. m. to 12 midnight. This period of illumination (15 hours) falls within the optimum range for tomato plants. Two wave-length ranges for two different light intensities were used. One wave-length range included all radiation transmitted by a water cell 1.5 cm thick with pyrex cover glasses, and the other was further limited by a heat-absorbing filter. Two chambers of each pair had the same visual intensity. It is realized, of course, that the radiant energy required in plant reactions is not exactly limited to the visible region, nor is it at all likely that their requirements are at all proportional to the visibility. It would be preferable to compare the effect of radiation in the range absorbed by chlorophyll with radiation including the near infra-red as well. Practical considerations make it necessary to use a heat-absorbing filter which cuts off not sharply at the limit of chlorophyll absorption, but gradually from 6,000 to 8,000 A. The method to be described for equalizing the visual intensities is simply a convenient means of attaining approximate equality of intensities in the visible range common to both types of radiation.

The light intensities were equalized at the beginning of the experiment by means of a Weston photronic cell provided with a special heat-absorbing filter (Corning heat-resisting, heat-absorbing, dark shade filter 2.82 mm thick). At the conclusion of the experiment of two weeks' duration the light intensities gave the values indicated in Table 1. This combination yielded a sensitivity curve shown as a continuous line in Figure 1. Sensitivity is plotted as ordinates in arbitrary units with 100 as maximum against wave lengths in Angstrom units. The visibility curve shown as the dash line is included in this figure for the sake of comparison.

The two distributions of energy, adjusted for equality for visible radiation measured as indicated, are shown in Figure 2. In order to determine the distribution of energy in the chambers with and without the heat-absorbing filters, a curve of relative emission per unit wave length of radiation for a tungsten filament at the absolute temperature of 2,980° K. was constructed. This tungsten radiation curve was then corrected for energy absorbed by the pyrex filters and 1.5 cm of water. Another curve was obtained by further correcting for energy absorbed by the heat-resisting, heat-absorbing light shade filter (8 mm thick) and 1.5 cm of water. From each of these two distribution curves corresponding response curves were drawn by

TABLE 1

Light sources and intensities

Chamber	Mazda lamp (watts)	Glass [a] of water filter	Illumination measured by Weston photronic cell with filter [b]	
			Microamps	Estimate of foot-candles
1	500	p and p	100	339
2	500	h and p	106	359
3	1500	h and p	580	1966
4	1000	p and p	580	1966

[a] p, pyrex; h, Corning heat-resisting, heat-absorbing, light shade filter, 8 mm thick.
[b] For these measurements a circular piece of Corning heat-resisting, heat-absorbing, dark shade filter, 2.82 mm thick was placed over the Weston photronic cell.

applying the factors obtained from the sensitivity curve of the photronic cell with its special heat-absorbing filter. The ratio of the areas under the two response curves then gave a factor which was applied to one of the distribution curves in order to adjust their relative values so as to yield equality of total response, that is, equality of visible radiation as determined by the photronic cell with its filter. These two adjusted curves are the ones presented in Figure 2. A comparison of the areas of these curves shows that the total energy applied to the plants receiving no near infra-red radiation was 22 per cent of that applied to the plants receiving radiation including the near infra-red.

Thermometers were hung in the chambers in such a manner that their bulbs were shaded from the direct rays of the lamps but were

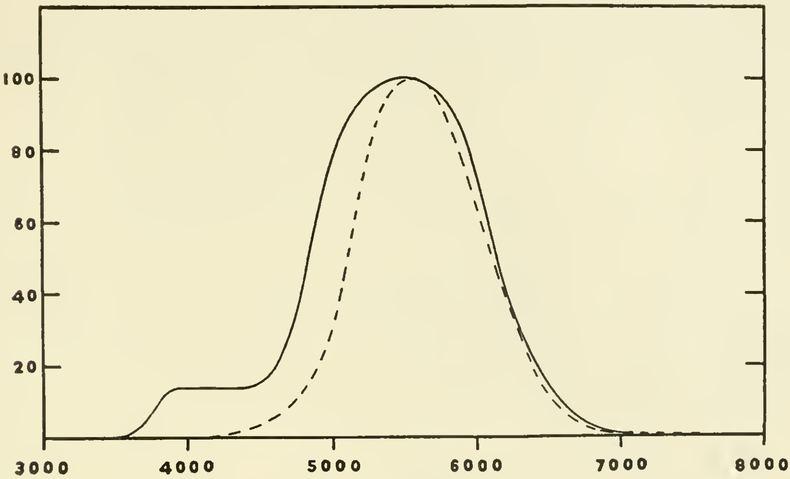

FIG. 1.—Sensitivity curve (continuous line) of a photronic cell provided with a special filter, and the visibility curve (dash line).

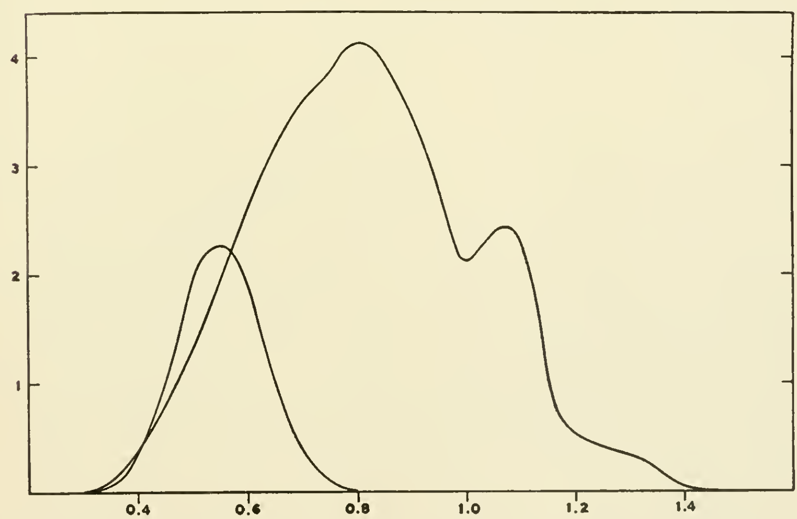

FIG. 2.—Curves showing the two types of energy distribution adjusted for equality of "visible" radiation as measured by the photronic cell with its special filter.

freely exposed to the air. Temperatures were usually read three times each day. During the light periods the temperatures were approximately 3.5° C. higher than during the dark periods. The average temperatures are shown in Table 2.

In this experiment no measurement was made of the rate at which air was recirculated through the chambers. Fresh air was injected into the system at the rate of 15 liters per minute. It should be emphasized that a sufficient rate of air movement in plant growth chambers is very essential. It is true, as has been discussed by Wallace (20), that some plants have been grown for several months in glass containers hermetically sealed. Few plants, however, are suited to such an existence and then only when there is a proper balance of mineral and gaseous elements, temperature, and light in their microcosm. In two previous experiments air was recirculated very slowly. Under these conditions the plants were very soon affected with oedema. Numerous frosty-white intumescences appeared on the midribs, petioles and stems. The leaves soon became twisted and contorted and finally gave the plant a wilted appearance as illustrated in Plate 2. Atkinson (4), Orton and McKinney (11), and others have described this disease as due to excess humidity, poor lighting, and overheating. With a low rate of air flow in the growth chambers the conditions are ideal for producing this disease. Further experimentation showed that with an air flow of 40 liters per minute per chamber all symptoms of oedema were entirely eliminated.

Table 2

Average air temperatures in the plant growth chambers

Growth chamber	1	2	3	4
Light period	24.4	24.5	25.3	25.9
Dark period	20.9	20.8	20.8	20.8

Marglobe tomato seeds were placed in the germinator on April 21, 1932, and the sprouted seeds removed to the germination net on April 26. Eight days later the young plants whose average height was 2.5 cm were set out in the culture jars and placed in the four growth chambers, four to a chamber. For comparison two groups of four plants each were grown under uncontrolled conditions in natural light, one group placed in a west window of a room in the Smithsonian tower, the other standing in the north window of the basement laboratory. At the end of two weeks the plants were photo-

TABLE 3

Plant data at harvest, expressed as averages per plant

Radiation						
Intensity	Low		High		Daylight	
Distribution[a]	V and I	V	V and I	V		
Plant group	1	2	4	3	West window	North window
Dry weight (mg)						
Tops	126	16	426	199	162	16
Roots	14	3	40	31	30	3
Total	140	19	466	230	192	19
Water absorbed (cc)	45	15	88	93	85	18
Stem height (cm)						
Final	20.2	6.8	18.0	12.7	7.8	5.6
Increase	17.2	4.4	15.6	9.9	5.4	3.5
Number of leaves	5.0	4.3	5.8	5.8	5.4	3.5
Order of greenness	4	1	5	3	4	2
Water requirement	320	810	188	402	444	956
Ratio $\frac{\text{root}}{\text{top}}$ wt.	0.11	0.17	0.09	0.15	0.18	0.17
Internodal index Ratio $\frac{\text{stem ht.}}{\text{no. of leaves}}$	4.0	1.6	3.1	2.2	1.3	1.4
Stem elongation Ratio $\frac{\text{(final ht.}}{\text{original ht.)}}$	6.7	2.8	7.5	4.5	3.3	2.7

[a] V and I, visible and near infra-red radiation; V visible radiation.

graphed and measured. The plant data obtained from these measurements are presented in Table 3.

In an examination of the data of this table it should be remembered that the visible intensities in chambers 1 and 2 were approximately the same. Likewise those of 3 and 4 were alike. However, in the latter pair the light was much more intense. In chambers 2 and 3 the infra-red was removed. A comparison of the dry weights shows the greatest growth to have occurred in chamber 4 and the least in chamber 2. In a subsequent experiment, similar to this one except that the temperatures were higher, the same order of growth, as measured by dry weight, existed between the four chambers. That is, in order of plant dry weight the series in this and a subsequent experiment was 4, 3, 1, 2 (high visible plus infra-red, high visible only, low visible plus infra-red, low visible only). It is also rather interesting to note that the growth of plants in chamber 2 (low visible) was very similar to that in the north window of the laboratory. Also there was a good deal of similarity between the plants in chamber 3 (high visible) and those grown in the west window of the tower.

A greater amount of water was absorbed by the plants exposed to the greater light intensities—those in chambers 3 and 4. It should also be noted that in chambers 1 and 4, where the proportion of red and infra-red was greater, the plants elongated much faster than those in chambers 2 and 3. Although there was little difference found in the average number of leaves of plants in the four chambers, there is an indication that more leaves were produced in the more intense light.

Attention is directed to the order of greenness of the plants grown under these six conditions of illumination. Those grown in chambers 2 and 3, which received only visible radiation, and in the north window were greener than the others. The lower leaves of the plants in chamber 4, where the radiation was more intense and included infra-red, had turned yellow. Those in chamber 1, while not as yellow as those in 4, were far from a healthy green color.

In the lower part of the table several derived values are tabulated. Water requirement is here considered as the amount of water absorbed by the plant during the two weeks of growth per unit of total dry matter. Plants in chambers 1 and 4, where infra-red radiation was present, were more economical in their use of water than the others. The ratios of root to top dry weights indicate that somewhat heavier roots in proportion to tops occur without infra-red.

The internodal index was determined by dividing the height of the plant by the number of its leaves. It gives a relative index of the length of internodes. This index as well as the ratio of final to original height of the plants shows that much less elongation occurs without infra-red.

Plate 3 shows the general appearance of the six groups of plants after two weeks of growth under the conditions of light mentioned in this paper. With the exception of set 1 all the individuals of the various groups are very uniform, with but slight variations. For better comparison a representative culture from each group was selected and photographed. These are presented in Plate 4.

DISCUSSION

Growth of plants under different wave lengths of light has received considerable attention at the hands of plant investigators. Much of this earlier work has been reviewed by Teodoresco (18, 19), who has done very valuable work along this line. He investigated two main spectral regions (the blue-violet and the red-orange) by means of colored solutions and glass filters. Because of the general conclusion of many previous investigators and his own experience that infra-red has no appreciable effect in addition to heating, he did not think it necessary to use water screens between his light sources and the plants. However, in measuring his light intensities a screen of water and copper acetate was used to eliminate the effect of the infra-red upon his measurements. His general conclusions from experiments with a large number of land plants, many of which were duplicated with both glass and solution filters, are: that in the longer wave lengths, internodes were elongated and more numerous, areas of leaves reduced, the leaves themselves were thinner, and a general abnormal configuration resulted. In the shorter wave lengths, growth in length was retarded, leaf area increased as well as leaf thickness. The general appearance of the plants was normal, resembling those grown in white light. In many respects the plants grown in the red-orange region resembled plants grown in darkness except for their green color. As Teodoresco points out, plants grown in darkness became etiolated without chlorophyll assimilation, so that growth ceases. In red light, however, the plants grow for a longer time than in darkness, due to the production of food by photosynthesis. In view of the fact that different color filters usually transmit different amounts of infra-red light, the existence of an effect of radiation in the near infra-red would necessarily qualify the conclusions to be drawn from such experiments. Consequently, the results of the present investigation raise serious doubts as to the validity of this type of experiment, unless it is definitely shown that the different filters transmit the near infra-red in the same degree.

Funke (7), working mainly with aquatic plants, studied the effects of three general spectral regions, red, green, blue, and subdued white light. Any ultra-violet or infra-red passing through his filters was neglected. The intensities behind these filters were approximately 25 per cent of the energy of diffused daylight. For many species the light intensity was insufficient. Results were obtained for plants in which photosynthesis was greater than respiration. The anatomy and behavior of plants in the blue light resembled those in full daylight. Those in red were " etiolated as in darkness (except of course that chlorophyll is formed). In green, phenomena are either the same as those in red or development is reduced to a minimum; the latter is undoubtedly due to a total absence of assimilation of carbonic acid. In gray, development now resembles that in blue, now that in red, depending on the needed quantity of blue rays being small or great."

Arthur, Guthrie, and Newell (3) have carried out a great many experiments on the growth of plants under artificial conditions and find the tomato the most sensitive to high light intensity in combination with a long day period of illumination. In three series they used respectively 5, 7, 12, 17, 19, and 24 hours of illumination daily, with an intensity of 450, 800, and 1,200 foot-candles. The air temperature of the first and second series was maintained at 78° F. and the third at 68° F. Their results show that the tomato will not withstand a 24-hour day of illumination at intensities which cause little or no injury to other plants. Even 19- and 17-hour days are injurious at the higher intensities. In the greenhouse experiments, where the plants were exposed to 12 hours daylight and 12 hours artificial light, the plants were injured. However, the rate of development of this injury was decreased by this combination of daylight and artificial light. The injury was characterized by the leaves becoming faintly mottled with necrotic areas appearing along the veins. The plants also had yellow leaves. The first signs of injury appeared in five to seven days.

In commenting on the illumination used these authors state:

> The energy value in the constant-light room calculated at 0.3 gram calory per square centimeter per minute amounts to approximately 12,960 gram calories per month of 30 days. The total for the month of solar and sky radiation as published by the New York Observatory for June, 1929, was approximately 11,903 gram calories. The two energy values are similar but, as already pointed out, the spectral distribution is in no way comparable. The glass-water filter in the constant-light room absorbs practically all radiation of wave-length longer than 1,400 mμ so that the total energy value of 12,960 gram calories includes only the visible region and the near infra-red of wave-length shorter than 1,400 mμ.

The experiments described in the present paper set forth the general growth characteristics of tomato plants grown under two ranges of wave lengths for two different intensities. One group of plants was exposed to light, a large proportion of whose energy was in the red and near infra-red region, the other exposed to light limited to the visible wave length region. Thus, an attempt is here made to separate any near infra-red effects from those brought about by other wave lengths.

The growth of these tomato plants as measured by their total dry weights clearly shows that the plants receiving infra-red radiation were considerably heavier, with less difference occurring in the stronger light. It is conceivable that if the illumination were further increased the plants receiving no infra-red would surpass in weight those receiving these longer wave lengths. Such an increase in illumination would undoubtedly have been beneficial since Arthur (2) found that where light of the same composition as sunlight was reduced to 35 per cent of full sunlight tomato plants thrived best. Assuming 10,000 foot-candles as a value for full sunlight, then an illumination of 3,500 foot-candles would be the optimum illumination for tomatoes. In these experiments the higher estimated intensity was 1,966 foot-candles, approximately half their optimum intensity.

The general form of the plants grown under the near infra-red radiation was somewhat characteristic of plants grown under shade conditions in that the internodes were long. However, the leaves were not small as might be expected for shade conditions. The water requirement was also lower than that of the plants receiving only visible radiation. This point is rather interesting because shading is usually considered an environmental factor increasing the water requirement of plants. Thus, some general growth habits of the plants exposed to the near infra-red radiation are common to plants grown under shade conditions and others to those grown under normal light conditions.

Although the dry weight production was greater for plants exposed to the infra-red radiation, these plants were distinctly less green than those receiving only the visible wave lengths. In the higher intensity of the infra-red the lower leaves were rather yellow. This evident destruction of chlorophyll in the near infra-red region is extremely interesting. Although considerable work has been done on growing plants in different colored lights, many of the early results are questionable because of inadequate light filters and a lack of suitable measuring devices for evaluating the intensity factors. In recent years many of these difficulties have been overcome.

Light within certain wave length and intensity limits is generally considered essential to chlorophyll formation, although it is true that certain pine seedlings and a few algae become green in darkness. As early as 1874 Wiesner (21) found that chlorophyll was formed in plants when illuminated by light passed through solutions of potassium bichromate and copper sulphate. These filters divided the visible spectrum into two parts. He also showed that no greening occurred in the nonluminous heat rays.

Sayre (15) studied the development of chlorophyll in seedlings of several varieties of plants by growing them under Corning glass ray filters and noting the relative greenness as compared with seedlings grown in full daylight. No greening was observed in wave lengths longer than 6,800 A. In the visible spectrum he found that for approximately equal energy values the red wave lengths were more effective for the development of chlorophyll than the green and the green more effective than the blue. The effectiveness apparently increased with increasing wave length up to 6,800 A, where it ended abruptly.

Shirley (16) working with several types of plants grown in the spectral greenhouses at the Boyce Thompson Institute for Plant Research found an increase in chlorophyll concentration with decreasing intensity to a point so low as to hazard the health of the plant. At approximately 10 per cent of full sunlight intensity the chlorophyll content was practically the same for wave lengths 3,890-7,200, 3,740-5,850 and 4,720-7,200 A.

Plants grown at high altitudes were found by Henrici (9) to contain less chlorophyll than similar ones grown at lower altitudes. As noted by Spoehr (17) " this is presumably due to the greater intensity of light at higher altitudes. However, whether the lower chlorophyll-content of plants grown under high illumination intensity can be directly ascribed to the destructive action of such light (especially the red-yellow rays) on chlorophyll, does not seem entirely established."

Tomato plants grown under ordinary greenhouse conditions and then placed under continuous artificial illumination were found by Guthrie (8) to show a marked decrease in their chlorophyll content in a few days. The leaves turned yellow and later showed necrotic areas. By analysis the chlorophyll decrease was greater on the dry-weight than the fresh-weight basis, due to a very large increase in carbohydrates. It is interesting to note that this author found a consistent lowering of the chlorophyll *a*/chlorophyll *b* ratio. Both *a* and *b* decreased under the effect of the light, but *a* decreased faster.

If radiation within certain wave length and intensity limits is necessary for the formation of chlorophyll and if, as appears probable, other radiation limits are destructive either directly or indirectly, then the amount of chlorophyll present in a leaf at a given time is the resultant of these two processes of production and destruction. According to Sayre, as noted above, the effectiveness of the wave lengths apparently increases up to 6,800 A., where it ends abruptly. In earlier experiments it appears that no distinction was made between the near and far infra-red, so that definite conclusions cannot be drawn. From the present experiments it would appear that the near infra-red has a decided destructive action on chlorophyll, even great enough to surpass its rate of formation in the presence of wavelengths shorter than 6,800 A. It should be remembered, however, that these tentative conclusions are based on the appearance of the leaves. Before definite conclusions can be drawn the experiments should be repeated and chlorophyll determinations made.

From the experiments of Arthur (1) on the production of pigment in apples it appears that the near infra-red radiation alone or in the presence of visible light has a marked detrimental effect on apples. Under these rays a typical wrinkled, necrotic area soon develops. In his work with tomato plants Arthur found that injury occurred with the use of continuous illumination even as low as 150 foot-candles. The fact that the rate of injury was greatly decreased where half sunlight and half artificial light was used emphasizes the necessity for a more thorough investigation of light sources whose distributions differ from that obtained with the Mazda lamp.

One point should not be lost sight of, namely, that in the region of the strongest chlorophyll absorption bands the plants grown in the distribution including the infra-red receive some three times greater intensity of radiation. This very likely in large measure accounts for the greater increase in dry weight exhibited by the plants grown under this distribution. It is furthermore likely that the higher internal temperatures produced by the more penetrating near infrared would account to some extent for other differences exhibited. In a future experiment it is hoped to compare two distributions in which the radiation in this region is approximately equalized. For this purpose it will be necessary to secure heat-absorbing filters which cut off at longer wave lengths.

CONCLUSIONS

The tomato plants that received both visible and excessive near infra-red radiation under the artificial conditions of these experiments showed some general growth habits common to both normal and shade-grown plants. The internodes were larger, the leaves larger, and the water requirement less than in plants grown under the visible radiation alone.

A marked decrease in chlorophyll occurred in the leaves of the tomato plants grown under the full visible and infra-red range of wave lengths. A distinct yellowing and death was noted in extreme cases. It appears that, if not actually destructive, this infra-red region of the spectrum is of little or no benefit to chlorophyll formation.

It would appear that normal growth of the tomato plant can be obtained under artificial light conditions where the infra-red is cut off and the intensity great enough.

From a review of the literature and from the results obtained in these experiments with the tomato plant it appears that the near infra-red region of the spectrum is of considerable biological importance.

Furthermore, experiments comparing the effects of different portions of the visible region must be scrutinized for the possible presence of different amounts of near infra-red.

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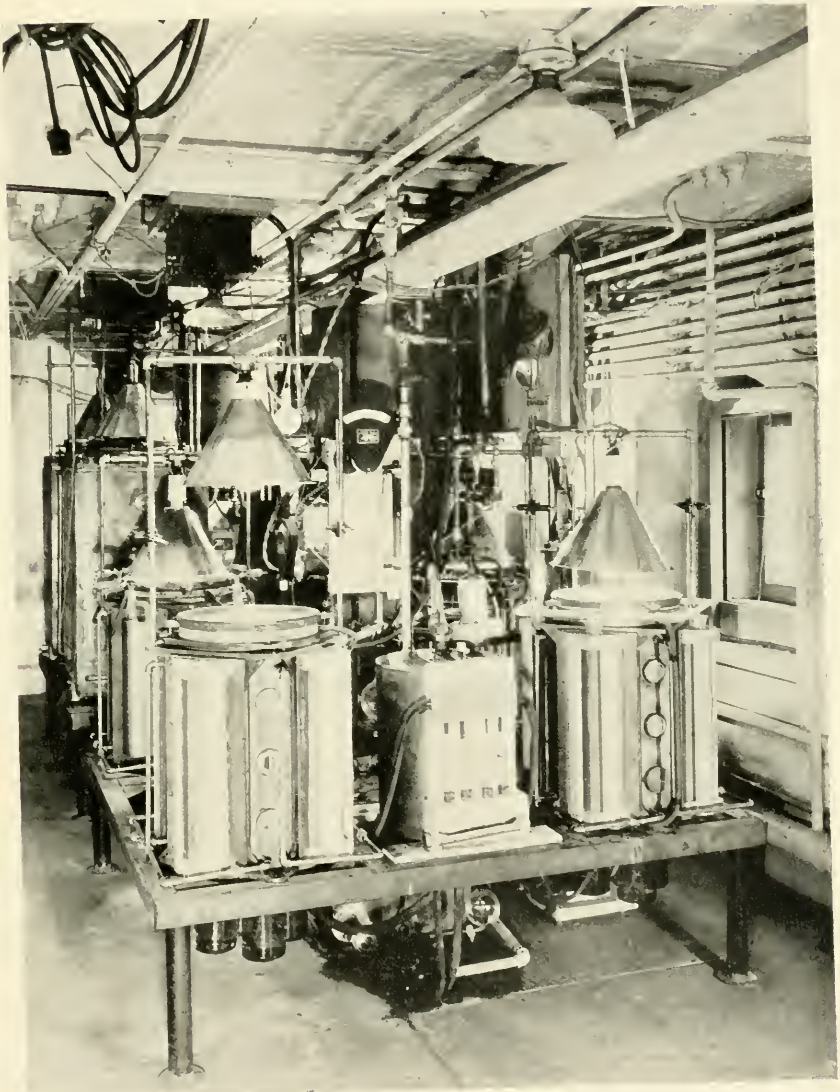
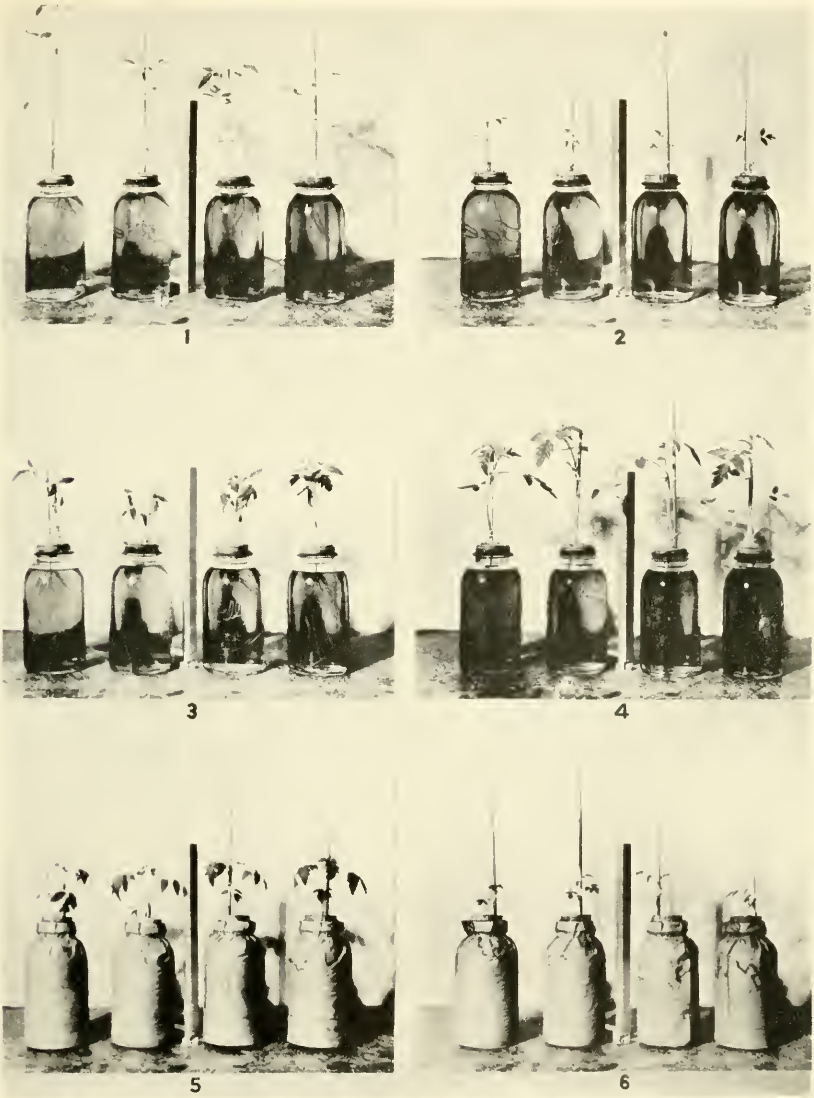


GENERAL VIEW OF PLANT GROWTH CHAMBERS AND EQUIPMENT FOR CONTROL OF EXPERIMENTAL CONDITIONS

Appearance of Tomato Plant Affected With Oedema Brought About by Poor Ventilation



APPEARANCE OF THE SIX GROUPS OF TOMATO PLANTS AFTER TWO WEEKS OF GROWTH

Low light intensity:
- Visible plus near infra-red 1
- Visible only 2

High light intensity:
- Visible plus near infra-red 4
- Visible only 3

Natural illumination:
- In west window of tower 5
- In north window of laboratory 6

APPEARANCE OF REPRESENTATIVE TOMATO CULTURES FROM EACH OF THE GROUPS ILLUSTRATED IN PLATE 3

Low light intensity:
Visible plus near infra-red........ 1
Visible only 2

High light intensity:
Visible plus near infra-red......... 4
Visible only 3

Natural illumination:
In west window of tower.......... 5
In north window of laboratory...... 6

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 87, NUMBER 15

Roebling Fund

AN IMPROVED WATER-FLOW PYRHELIOMETER AND THE STANDARD SCALE OF SOLAR RADIATION

(With One Plate)

BY
C. G. ABBOT and L. B. ALDRICH
Smithsonian Institution

(Publication 3182)

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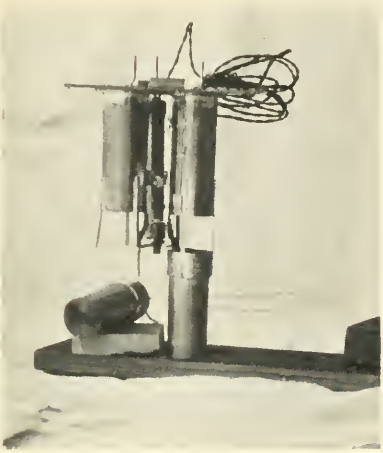

1. Water-flow pyrheliometer No. 5 disassembled.

2. Water-flow pyrheliometer No. 5 assembled.

3. L. B. Aldrich reading silver-disk pyrheliometer S.I.5_{bis} as mounted with water-flow pyrheliometer No. 5 for comparison.

AN IMPROVED WATER-FLOW PYRHELIOMETER AND THE STANDARD SCALE OF SOLAR RADIATION

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(With One Plate)

In 1927, V. M. Shulgin[1] suggested an improvement of the water-flow standard pyrheliometer.[2] He pointed out, and our experience abundantly confirms it, that fluctuations of the rate of flow and of the temperature of the water lead to irregular drift and wiggle of the galvanometer record in the use of such an instrument, for instance, as water-flow pyrheliometer No. 3. These irregularities make up a principal part of the total error in using the instrument as described by us in Volumes 3 and 4 of the Annals of the Astrophysical Observatory. Shulgin's improvement consists in duplicating the instrument so as to have two chambers instead of one. He divides the current of water nearly equally between them. Solar radiation is introduced in one chamber, and compensating electrical energy in the other. Thus a null method is substituted for the deflection method, and the irregularities of the water current are eliminated as a source of error because they affect both chambers equally and simultaneously.

We wholly approved of Shulgin's principle but felt that a more favorable mechanical and electrical expression than his could be given to it. Accordingly, by the skill of A. Kramer, mechanician, we duplicated last winter the water-flow pyrheliometer No. 3, described at page 52 of Volume 3 of the Annals. We combined the two chambers thus made available to form a new standard water-flow pyrheliometer No. 5. In combining the two instruments, in order to control surrounding conditions, we added a common enclosing metallic case whose hollow walls were bathed by a separate current of tap water. We also arranged a common entrance pipe for the distilled water used in the measurements. This entering water stream was protected by a closely surrounding Dewar vacuum enclosure and was well stirred by a baffle circulatory system. To determine the equality of temperatures of the

[1] Monthly Weather Rev., August, 1927.

[2] See description of this instrument, Ann. Astrophys. Obs., Smithsonian Inst., vol. 3, p. 52, 1913.

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water streams outflowing from the two chambers we employed eight thermoelectric junctions of nickel-platinum connected in series with their elements passing alternately from one stream to the other. Short glass outflow tubes pierced to admit these thermoelectric elements were skilfully made by L. B. Clark of this Institution. These delicate parts of the apparatus were enclosed completely by an air-tight box made of cellophane and wax. Thus air currents could not directly affect the thermoelectric system. Plate 1, Figures 1, 2, 3, show the instrument in various stages of completion as thus constructed and used. The electric heating coils are wound on the rear surfaces of the receiving cones at the extreme rear of the absorption chambers. In water-flow pyrheliometer No. 3 we wound heating coils not only in that position, but also on the front edges of the cone. We found in our use of that instrument that coils in these two positions give equal results; hence we felt justified in omitting the edge coils in water-flow pyrheliometer No. 5.

With the cooperation of Doctor Süring, Messrs. Abbot and Martens compared at Potsdam in October, 1931, silver-disk pyrheliometers S.I.5_{bis} and S.I.12. The latter instrument has been for about 20 years in the possession of the Meteorological Observatory at Potsdam. The constant of S.I.5_{bis}, 0.3715, as used last October, was determined by Messrs. Abbot and Hoover in August, 1931, by 24 comparisons with A.P.O.$8_{bis\ bis}$. We have used the latter instrument since 1912 solely for standardizations at Washington. Using this constant, 0.3715, readings of pyrheliometer S.I.12 were found to satisfy within 0.3 per cent the identical constant found for it in 1912. In order to carry through a direct comparison with S.I.12 in use at Potsdam, we employed at Mount Wilson in June, 1932, silver-disk pyrheliometer S.I.5_{bis} as the comparison instrument, together with our improved water-flow pyrheliometer No. 5. For convenience of observing, the latter was supported in a fork carried by an equatorial telescope mounting, and pyrheliometer S.I.5_{bis} was so attached that its tube for admission of solar rays was exactly parallel to the two tubes of No. 5. In this way the observer of S.I.5_{bis} kept No. 5 as well as S.I.5_{bis} continually pointing at the sun during comparisons. Times of reading of the silver disk pyrheliometer were governed by a sounder beating seconds. Observers C. G. Abbot and L. B. Aldrich interchanged duties in reading the pyrheliometers. No difference in result was noted.

Water currents of approximately 45 cubic centimeters per minute in each branch of pyrheliometer No. 5 were found to give good results, but different rates of flow were tried at various times without affecting the results of the comparisons of pyrheliometers. There was a deflection of about 9 centimeters on the scale of the moving coil galvanometer when sun rays were allowed to enter one chamber of pyrheliometer No. 5 without electric compensation. No wiggle as great at 0.01 centimeter was ever detected during observations. Accidental fluctuations were therefore less than 1/1000 part of the deflections. Slow drift of a millimeter or two during a run of half an hour sometimes occurred, but was eliminated by alternating the chambers exposed to solar and electric heating. In short, water-flow pyrheliometer No. 5 behaved far better than we had expected and indeed so perfectly that we can not conceive of its improvement.

In the use of it, we at first regarded as the zero of the galvanometer that position on the scale which was assumed when no outside energy of sun or electricity was entering either chamber. There was then considerable inequality in the results from the two chambers. Later we perceived the advantage of using as galvanometer zero the position assumed when solar rays were shining fully into both chambers simultaneously. Using this zero, the results from the two chambers were then very nearly equal, usually within 1 per cent. But no difference in the mean result of the comparisons with S.I.5_{bis} was discerned, whichever zero was employed.

In using the water-flow pyrheliometer No. 5, we found that an exposure of two minutes before interchanging chambers was ample. It is clear that a certain time must be allowed to elapse before interchanging, for the electric heating is applied where the water current is about to issue from the chambers. A small part of the solar heating, on the other hand, is absorbed near the front orifices of the chambers. From that location the current of water must flow several meters through its spiral channel within the hollow walls of the chambers before emergence. Hence the full effect of electric heating reaches the thermoelectric junctions quicker than can the full effect of solar heating. It is therefore necessary to wait until both sources of heating can exert their full effects before making a balance. We assured ourselves that two minutes was ample time for this by trying much longer exposures and finding thus no change of the results of comparisons of pyrheliometers.

The accuracy of the results with water-flow pyrheliometer No. 5 does not depend on any measurements of the rate of flow or of the temperature of the water.[3] It depends on the measurement of the

[3] The question of temperature concerns us only in reducing the electric energy in joules to its equivalent in calories. We use the factor 4.185 to reduce to 15° calories.

areas of the solar apertures, on the adjustment of the heating current to reproduce exactly the observed zero reading of the galvanometer, and on an exact determination of the electric heating current required. The solar apertures were turned truly circular and equal, and a plug exactly fitting them was made. This plug was inserted from time to time during observations to surely clear the aperture of dust particles. It was measured at numerous diameters with two different Browne & Sharpe micrometers. The mean value was 2.312 centimeters. The computed area of the aperture was thus found to be 4.198 square centimeters. Two milliammeters in series were used to measure the currents. One of them was a more satisfactory instrument than the other, and its results were used exclusively in the final computations. The others differed from them only very slightly. These electric instruments were calibrated several times during the measurements against new Weston standard cells. It is believed that the errors of individual current measurements did not exceed 0.1 per cent, so that the errors of individual energy measurements, due to inaccuracy in reading the current values, did not exceed 0.2 per cent. In the mean of many observations given below this error would be sensibly eliminated.

We computed the loss of solar radiation by reflection through the entrance of the receiving chamber and made a plus correction of 0.1 per cent for the imperfect "blackness" due to it.

In our earlier days of observing in June, 1932, the sky was very exceptionally clear at Mount Wilson. Observed values of radiation reached 1.53 calories according to silver-disk pyrheliometer S.I.5_{bis} notwithstanding that the earth was then in aphelion, and besides, the temperature being high, the atmospheric humidity was considerable. At that time we used the water-flow pyrheliometer No. 5 with exactly the same sky exposure as that described for No. 3 in Volume 3 of the Annals, which had an angular aperture as viewed from the limiting diaphragm of about 16°. The silver-disk pyrheliometer S.I.5_{bis}, on the other hand, was of our modern improved type, exposing only 5° 48′ angular diameter as viewed from the silver disk, or 0.0013 hemispheres. Fearing that the June measurements of the two instruments would not be quite comparable, despite the exceptional clearness of the sky, we subsequently erected a double highly reflecting screen in front of pyrheliometer No. 5 designed so as to give it exactly the same sky exposure as S.I.5_{bis}. We repeated the comparison on July 8 with these arrangements but obtained almost exactly the same results as before.

The following table includes all the comparative observations of pyrheliometer S.I.5_{bis} and water-flow pyrheliometer No. 5, except a

SUMMARY

Date 1932	Time	Calories by water-flow No. 5	Corrected reading of S.I.5$_{bis}$	Constant of S.I.5$_{bis}$	Deviation from mean
June 26	10^{h}11^m	1.461	3.950	0.3699	+74
	17	1.460	4.007	.3644	+19
	23	1.467	4.031	.3639	+14
	29.5	1.465	4.008	.3655	+30
	38	1.469	4.049	.3628	+ 3
	42	1.472	4.059	.3626	+ 1
	48	1.464	4.084	.3586	−39
	11 22	1.470	4.033	.3645	+20
	26	1.485	4.064	.3654	+29
	30	1.473	4.058	.3630	+ 5
	35	1.485	4.058	.3659	+34
	40	1.488	4.117 (?)	.3614 (?)	−11
	1 44	1.460	4.021	.3631	+ 6
	47	1.450	4.046	.3584	−39
	53	1.453	4.023	.3612	−13
	57	1.452	4.053	.3583	−42
	2 11	1.451	4.021	.3609	−16
	22	1.447	3.965	.3649	+24
	25	1.455	3.961	.3673	+48
	31	1.438	3.986	.3608	−17
	34	1.438	4.035	.3564	−61
			Mean, 21 values	.3628	
June 27	9 50	1.495	4.101	.3645	+20
	54	1.507	4.133	.3646	+21
	10 05	1.497	4.168	.3592	−33
	10	1.498	4.178	.3585	−40
	52	1.502	4.140	.3628	+ 3
	57	1.508	4.148	.3635	+10
	11 04	1.502	4.164	.3607	−18
	08	1.505	4.164	.3614	−11
	32	1.523	4.190	.3635	+10
	37	1.520	4.211	.3610	−15
	43	1.530	4.216	.3629	+ 4
	48	1.530	4.215	.3630	+ 5
			Mean, 12 values	.3621	
July 8	10 14	1.411	3.866	.3650	+25
	23	1.402	3.890	.3604	−21
	36	1.390	3.852	.3609	−16
	44	1.406	3.885	.3619	− 6
			Mean, 4 values	.3621	

Mean of 37 observations (3 days) 0.3625
Average deviation, 0.00217
Probable error, 0.00030, or 0.08 per cent

few preliminary ones of June 24, at which time the silver-disk pyrheliometer measurements were affected by a timing error. From these comparisons the constant of pyrheliometer S.I.5_{bis} results as 0.3625.

Many comparisons were made at Washington in August, 1931, and in September, 1932, between silver-disk pyrheliometers S.I.5_{bis} and A.P.O.$8_{bis\ bis}$. The latter instrument has been used for many years to standardize silver-disk instruments sent abroad. The former was furnished with 12-1/2 inch vestibule and the other changes made upon it in August, 1931. The comparisons just referred to resulted as follows:

Date	Number of comparisons	Ratio $\frac{S.I.5_{bis}}{A.P.O.8_{bis\ bis}}$
Aug. 8, 1931	8	1.0206
Aug. 17, 1931	18	1.0177
Sept., 1932	8	1.0170
	Weighted mean	1.0182

According to these results and to the observations made with Standard No. 5, the constant of A.P.O.$8_{bis\ bis}$ could now be taken as 0.3691. We have hitherto adopted 0.3786. A change of − 2.5 per cent is indicated.

Is this difference to be regarded as due to error in the experiments with our water-flow and water-stir pyrheliometers No. 3 and No. 4 with which we established the Smithsonian scale of 1913? First of all we recall that in the use of these instruments at Washington and Mount Wilson their sky exposure, reaching an angular diameter of about 16°, is to be contrasted with the sky exposure to only 10° 38′ in the original silver-disk instruments. More than twice as much sky area was observed by the standard instruments as by the silver-disk pyrheliometers in 1913. This may have made several tenths of a per cent too high a scale value in the work of 1913.

In the second place, the calibration of the platinum resistance thermometers used in standard pyrheliometers No. 3 and No. 4 involved the whole technique of exact mercury thermometry. Those who have had occasion to use mercury thermometers for exact work will know what was involved in the determinations of temperatures, as given in Tables 10 and 19 of Volume 3 of the Annals, and that appreciable inaccuracy there may have been possible. Indeed, the irregularity of run of the numbers in the latter part of Table 10 seems to throw some doubt on the sufficient accuracy of the coefficients of temperature change determined.

In the third place, we pointed out, as Shulgin has done also, that irregularities of flow of the water current in the use of standard pyrheliometer No. 3 caused galvanometer drift and wiggle, and difficulty in deciding as to the true deflections due to solar heating. Personal equation might well enter in such a case, and there may have been a tendency to read the deflections too large.

As compared with all these complex and numerous sources of error in the older standard pyrheliometer, the extreme simplicity and perfect operation of standard pyrheliometer No. 5 must strongly incline us to attribute very much greater weight to its results.

In the fourth place, we have altered the silver-disk pyrheliometer vestibules in recent years to expose only to an angular diameter of 5° 48′. In making this change of vestibules of $A.P.O.8_{bis}$ on December 1, 1927, it is possible that some slight structural modification of the pyrheliometer occurred. We did, indeed, make careful comparisons of $A.P.O.8_{bis}$ with silver-disk instrument S.I.5 before and after the change. These comparisons resulted as follows:

Date	Number of comparisons	Ratio $\frac{S.I.5}{A.P.O.8_{bis}}$	Ratio $\frac{S.I.5}{A.P.O.8_{bis\ bis}}$
Apr. 15, 1911	7	1.0389	......
Dec. 20, 1912	18	1.0281	......
Oct. 14, 1921	12	1.0339	......
Mar. 6, 1922	20	1.0291	......
Oct. 10, 1927	8	1.0457	......
Oct. 22, 1927	20	1.0305	......
Nov. 1, 1927	20	1.0395	......
Dec. 1, 1927	8	......	1.0328
Dec. 27, 1927	8	......	1.0311
Feb. 27, 1928	8	......	1.0422

Allowing for the almost unavoidable irregularities of such comparisons over so long a time, due to sky conditions, personal equation, and watch eccentricity, there is nothing here to indicate any change of constant of $A.P.O.8_{bis}$ with respect to S.I.5. The latter instrument had not been changed at all during all this time. The weighted mean values are as follows:

Date	No. of values	Weighted mean ratio
1911-1922	57	1.0310
Mar.-Nov., 1927	48	1.0368
Dec., 1927-Feb., 1928	24	1.0354

Pyrheliometer S.I.5 after these experiments was altered early in August, 1931, as explained on a preceding page and called S.I.5_{bis}.

Other comparisons support the view that pyrheliometer A.P.O. $8_{bis\ bis}$ still gives fairly the standard scale of 1913. Thus the comparisons referred to on a preceding page made in Potsdam in October 1931 on exceptionally clear days indicate through S.I.5_{bis} and A.P.O. $8_{bis\ bis}$ for S.I.12 the constant 0.3624. The original calibration made in September 1912 resulted 0.3631. Again a long series of comparisons between A.P.O.8_{bis} and S.I.1 from 1911 to 1920 indicate even greater constancy than the set of comparisons with S.I.5 just quoted.

On the whole, therefore, we are forced to conclude that the standard scale of radiation as indicated by water-flow pyrheliometer No. 5 lies 2.5 per cent below the Smithsonian scale of 1913. The great simplicity and freedom from accidental error in the measurements of standard No. 5 warrants very high weight for its results compared to those obtained from pyrheliometers No. 3 and No. 4. In confirmation it may be added that a long series of unpublished measurements made by Messrs. Abbot and Aldrich with No. 3 at Mount Wilson in the year 1920 also tended to give results below the scale of 1913. We hope, however, to make additional experiments on this question next summer.

In our solar-constant values hereafter to be published, we regard comparability with preceding ones as more important than absolute scale. Hence we shall not introduce our new scale into such future publications. We may remark, however, that if applied to our mean value, 1.940 calories per square centimeter per minute, for the solar constant of radiation, it would become as corrected 1.893. We have admitted, however, our belief that a contrary small correction of undetermined magnitude should be applied to allow for extreme ultraviolet rays not observed, some of which cannot enter the atmosphere through the ozone layer.

In his publication " Ein neues Pyrheliometer für Absolutmessungen," C. Tingwaldt gives a preliminary result obtained by experiments at Davos. This indicates a plus correction of 1.9 per cent to the Ångström scale, and according to Tingwaldt indicates a minus correction of 1.8 per cent to the Smithsonian scale of 1913. Our own correction is in that direction, but of greater magnitude. We hope that further experiments on very clear days may be made by Tingwaldt and his colleagues, in which silver-disk pyrheliometer S.I.12 will be the comparison instrument. We shall then be in a position to evaluate very closely the difference, if any, between our new water-flow pyrheliometer No. 5 and the absolute pyrheliometer used by Tingwaldt.

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(WITH TWO PLATES)

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INTRODUCTION

Carbon dioxide assimilation of young wheat plants grown under controlled environmental conditions has been determined for a wide range of radiation intensities and carbon dioxide concentrations. Special growth chamber and control equipment have been developed for determinations using the entire plant. The purpose of this investigation is to determine the possibilities and limitations inherent in such technique for the investigation of photosynthesis.

The use of excised leaves common in such investigations, while offering the advantage of more ready isolation and control, and lending itself to better radiation distribution, raises many questions regarding the possible influence of accumulated end products and abnormal growth conditions. Work with algae has many advantages, chief among them being (1) avoidance of shielding, (2) the maintenance of definite temperature through immediate contact with water (owing to the high heat capacity of water, the actual temperature of the algae structure cannot differ perceptibly from the observed temperature of the surroundings), (3) because of their small size, unicellular algae offer the possibility of greater simplification and wider latitude in methods of illumination. Disadvantages common to the algae work however are (1) problems of diffusion of gas through the nutrient solution, and (2) the difficulties of obtaining suitable buffer solutions which can maintain algae continuously in a healthy condition over a long period. A great deal of work in this field has been done in such solutions that algae can exist only for a few hours. This again raises questions as to the influence of physiological factors upon the reactions. These difficulties common to most of the earlier work have been to a considerable extent overcome by Van den Honert.[1] Our observations

[1] Van den Honert, T. H., Carbon dioxide assimilation and limiting factors. Rec. trav. bot. neerl., vol. 27, pp. 149-286, 1930.

offer an interesting basis for the comparison of photosynthesis in higher plants with his observations on algae. A discussion of this comparison will be taken up in connection with our experimental data.

GROWTH CHAMBER AND CONTROL EQUIPMENT

The problem of controlling the various factors affecting the rate of photosynthesis is somewhat simplified by construction of a growth chamber designed for tall slender plants such as wheat, which can be

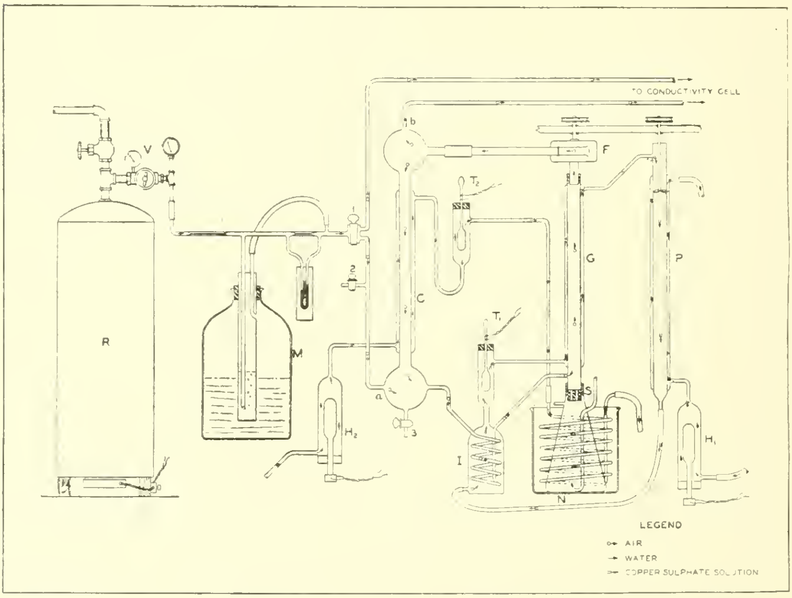


FIG. 1.—Diagram of plant growth chamber (G) with auxiliary control systems.

confined in a narrow tubular space. The simple form of the apparatus depends to some extent on the fact that the plants are grown in nutrient solution. A general view of the apparatus is shown in Plate 1.

Figure 1 is a diagrammatic drawing of the growth chamber and the necessary auxiliary apparatus for controlling the air–carbon dioxide supply, temperature, and humidity. The light intensity was controlled by the number, size, and distance of the incandescent lights placed symmetrically around the growth chamber.

The growth chamber, G, consists of a double-walled glass tube about 90 cm long and 2.6 cm inside diameter with the inner tube extending about 5 cm below the seal with the outer tube. The inside diameter of the neck of the flask, N, which holds the nutrient solution, is somewhat greater than the diameter of the inner tube of the growth chamber. The two are connected by a rubber annulus, S. The plants are supported by inserting them through small holes in a paraffined cork stopper which fits into the lower end of the growth chamber. The cork, in addition to supporting the plants, separates the flask of solution containing the roots from the space occupied by the tops of the plants. The roots are aerated by passing air through a tube sealed in the side of the flask and extending to the bottom, the air escaping through a side tube near the top of the flask. Air for the plant stems and leaves is admitted through a glass tube entering the growth chamber just above the stopper.

The supply of air containing any desired concentration of carbon dioxide is derived from a 50-gallon galvanized iron tank, R. Air in this tank under a pressure of 75 pounds per square inch is sufficient for the plants for a period of 14 to 16 hours. An electric heater is placed on the bottom of the tank to insure rapid mixing of the air and carbon dioxide.

The rate of flow of the air is regulated by means of the flowmeter, M, reducing valve, V, and capillary tube. The capillary tube is inserted in the air line between the reducing valve and the flowmeter to produce a back pressure, as the reducing valve does not regulate well unless the back pressure is 8 pounds per square inch or more. This precaution insures that a sufficient quantity of air is delivered to the flowmeter for all pressures in the tank between 10 and 75 pounds per square inch. The flowmeter used is designed to maintain a constant pressure difference between the intake and the discharge, for small changes of pressure on the discharge side. To prevent leakage of carbon dioxide the entire air system is made of glass, with the exception of the recirculating air pump, F, and three short rubber connections. The rubber connections are coated with paraffin. To test for a possible leakage of carbon dioxide the entire apparatus was assembled, without plants, and the concentration of carbon dioxide in the air measured before and after passing through the apparatus. No change in the concentration was detected.

A two-way stopcock is placed in the air line at 1, one branch leading directly to the carbon dioxide measuring apparatus for determining the original concentration of carbon dioxide, and the other leading to the growth chamber. During a determination of the original concentration, air is supplied to the plants through stopcock 2.

The flowmeter is adjusted to give 600 cc of air per minute. Under extreme conditions the plants absorbed as much as one half the available carbon dioxide. It is necessary, therefore, to recirculate the air in order to reduce the change in concentration of carbon dioxide along the plants. The air is recirculated by pump F, the direction of circulation, as indicated by the arrows, being down the double-walled tube, C, through the coil in I, and up through the growth chamber. Air enters the circulating system at *a* and is discharged at *b* for analysis. Pump F delivers about 21 liters of air per minute. Thus the effective quantity of air passing over the plants is increased by a factor of 35. If we assume the air entering at *a* contains .04 per cent carbon dioxide and the air discharged at *b* .02 per cent, the difference between the two or .02 per cent represents the amount absorbed by the plants. If the air is not recirculated the change in concentration of carbon dioxide along the plants amounts to 50 per cent. Since the effective flow has been increased by a factor of 35, the actual change in carbon dioxide concentration along the plants is $.02 \div 35$, or .00057 per cent of the total gas supply. Then if .02 per cent represents the concentration of the discharged air, .02057 per cent represents the concentration of carbon dioxide in the air entering the growth chamber. This amounts to a change in concentration along the plants of 2.77 per cent of the initial concentration. This represents about the maximum change in the course of the experiment.

Temperature control.—Water is recirculated through the space between the walls of tube G by a small propeller in the inner tube of P, through the cylinder, I, and the small bottle containing the thermostat, T_1. A continuous stream of water flows past the electric heater, H_1, and through the space between the walls of P. A resistance in series with the heater is adjusted to give about the desired temperature and the final regulation obtained by the thermostat, T_1, which changes the resistance in series with the heater. There is some lag in this method of controlling the temperature, but thermometers at the two ends of the growth chamber showed differences of only one half of a degree or less.

Humidity.—The tube, C, is maintained at a temperature of about 3° C. below the temperature of the growth chamber by a continuous flow of water past the heater, H_2, the tube, C, and past the thermostat, T_2. In order to hold the humidity constant it is necessary to have the humidity of the air supply high enough so that the addition of moisture due to transpiration will produce saturation at the temperature of C; any excess will be condensed on the walls of tube C. Due to the rapid recirculation of air we have air saturated at the temperature of C raised to the temperature of the growth chamber in I. From these data the relative humidity may be calculated. This calculated value is not exactly the humidity in the growth chamber, since moisture is added by transpiration of the plants and the recirculated air is mixed with the air supply at the bottom of tube C. The error, however, is small since the temperature of tube C may be raised to within half a degree Centigrade of the temperature of G without moisture collecting in tube G.

The roots of the plants are kept at a fairly constant temperature by passing the water from tube C through a coil immersed in water surrounding the flask of nutrient solution.

Illumination.—The plants were illuminated by means of eight 500-watt Mazda lamps arranged in two planes perpendicular to the axis of the growth chamber. The two planes were 30 cm apart, and the lights in each plane were equally spaced around the growth chamber. The light intensity was varied by varying the distance of the lamps from the plants. A thermocouple with a cylindrical receiver, constructed in this laboratory, was used to measure the intensity. Intensity measurements were made by a thermocouple placed within the growth chamber. For each position of the lights determinations were made at several points along that portion of the tube which was occupied by the plants during observation. A mean of these values was taken, and these mean values were assumed to be proportional to the average intensities on the surface of the leaves. During an experiment the thermocouple was kept at a fixed position in the tube in order to control the illumination.

To express the intensity of radiation in watts per cm^2 the thermocouple was calibrated against a standard radiation lamp yielding a calibration factor, 3.56×10^{-4}. Thus, reducing the light intensities given in Table 2 to absolute units we get for the maximum and minimum .0689 and .0058 watt per cm^2 respectively, or in terms of calories, .985 and .083 calorie per cm^2 per minute. The intensity as determined by the thermocouple is not the true intensity at the surface of a single leaf, for a single leaf does not receive energy from all the lights. Since the lights are equally spaced around the plants a leaf with its surface perpendicular to the incident beam from one of the lights would receive energy from only one light in each plane. For any other positions of the leaf it would receive energy from two lights in each plane, but since the radiation impinges on the surface at an angle the energy received from the two lights is practically equal to that which would be received from one at normal incidence. Thus we may take ¼ of the above values, or .246 and .021 calorie per cm^2 per minute as the approximate limits of the radiation intensity on the surface of the leaves.

Measurements of the light intensity were also made with a photronic cell in order to express the results in foot-candles. The photronic cell, with a dark shade heat-absorbing filter, giving a resulting sensitivity curve approximating the visibility curve, was calibrated against a standard of illumination. Readings of the photronic cell, at any particular light intensity, were taken at various vertical positions along the growth chamber and at various orientations. A mean of these readings is taken as the mean intensity on the leaf surface. In order to convert the value given in arbitrary units to value in foot-candles, multiply by 4.96. The above limits of intensities expressed in foot-candles are 947 and 80, respectively.

It is interesting to compare the light intensities used in this experiment with the total solar intensity. The daily values of the total solar radiation received on a flat surface, expressed in calories per cm^2, are given in the *Monthly Weather Review*. On cloudless days in Washington during May and June the total solar radiation may be as high as 600 or 700 calories per cm^2. On the basis of a 10-hour day we may conclude that the average solar intensity for cloudless days during these months is approximately one calorie per cm^2 per minute. The intensities used in this experiment varied from 0.021 to 0.246 calorie per cm^2 per minute. Thus the intensities used varied from 1/48 to ¼ that of sunlight.

APPARATUS FOR MEASURING CARBON DIOXIDE

The apparatus [2] for determining the carbon dioxide content of the air, shown in Figure 2, is one developed and built at the Fixed Nitrogen Research Laboratory, United States Department of Agriculture, and loaned to us for this work. The principle is to scrub a definite volume of the air with a definite volume of potassium hydroxide solution and to determine the titer of the resulting solution by means of its electrical conductivity.

The flow of the KOH solution (in this case .02 N) from the large reservoir, R, is maintained fairly constant by means of the constant level device, S, so that the liquid falls from the tip of the capillary tube, A, in drops of uniform volume at intervals of about eight seconds. Each drop falls through the bulb, B, upon the opening, C, trapping the air in the tube, CD, and forcing it along to the constriction in the tube at E. The constriction in the tube is of such size and shape as to arrest the drop at this point until displaced by the impact

[2] White, Ernest C., An apparatus for continuous gas analysis. Journ. Amer. Chem. Soc., vol. 50, pp. 2148-2154, 1928.

of the next drop at C. The air to be analyzed enters through the tube, N, and is brought to the temperature of the bath before entering the bulb, B, by passing through the coil, O. Since only a small portion of the air is used for analysis the excess escapes through the side

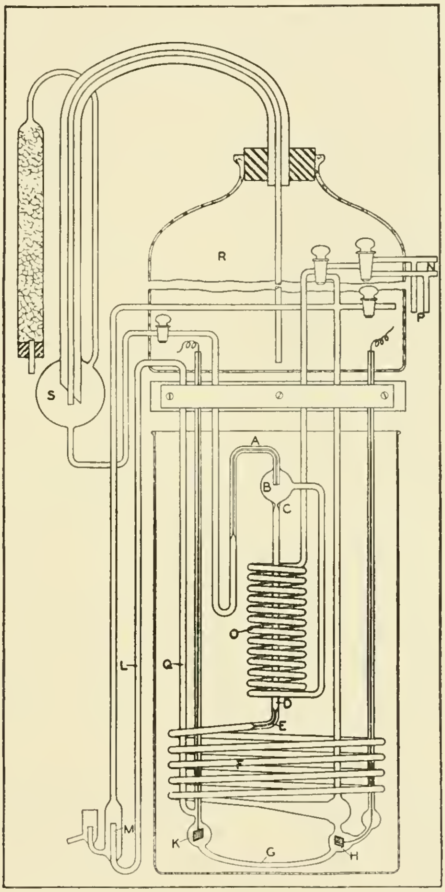


FIG. 2.—Diagram of apparatus for carbon dioxide determination.

tube, P. After the air and KOH solution have been brought together in definite proportion by volume they traverse the coiled tube, F, sufficiently long to insure practically complete absorption of the carbon dioxide. They are separated at the bottom end of the coil, F, which is widened at this point to disrupt the liquid film, the liquid flowing into the cell, HGK, and the air escaping through the tube. The overflow from the cell passes out through the siphon, L, the outer portion being bent up so that the end, M, is slightly higher than the electrode, H. The cell is a few centimeters of small-bore glass tubing bent upward at the two ends to prevent bubbles of gas collecting on the walls. The electrodes, H and K, are made of platinized platinum.

As the sensitivity required for this work was greater than that for which the apparatus was originally developed it was necessary to improve the temperature control and eliminate to a greater degree the effects of polarization. For temperature control a special thermostat was developed, whose bulb was a cylinder of annular section. This has the advantage of securing a maximum of exposed surface with a minimum of heat capacity. This thermostat was of the liquid expansion type, using carbon tetrachloride as the working material. The temperature fluctuation was limited to $\pm 0.005°$ C. Accurate control of the temperature is necessary, since the conductivity of the cell changes rapidly with temperature.

The conductivity of the solution was determined by making the cell one arm of a Wheatstone's bridge. To reduce the amount of polarization when using direct current on the bridge the direction of the current through the cell was reversed several times a second by a special commutator running in oil. There were also contacts on the commutator to short-circuit the galvanometer during the time of reversal. Very consistent results were obtained in this manner when the speed of the commutator was held constant.

For obtaining a zero point means were provided to recirculate the air inside the apparatus by connecting the exhaust with the intake. Thus in a short time the carbon dioxide was completely absorbed from the recirculated air and the conductivity cell filled with standard KOH solution.

Since small concentrations of carbon dioxide were used, a calibration of the apparatus was determined from the available conductance data and a measurement of the volume of air associated with each drop of solution. At a pressure of 760 mm and a temperature of 25° C. the volume of air is 3.125 cc and the volume of each drop is .0991 cc. The volume of carbon dioxide under the above conditions, necessary to neutralize .0991 cc of .02N KOH, is .02444 cc. Thus $.02444 \div 3.125$ gives .782 per cent, the concentration of carbon dioxide in the air necessary to neutralize the KOH solution and fill the cell with $\frac{1}{2}K_2CO_3$. From the conductance data we find the equivalent conductance of .02N KOH and $\frac{1}{2}K_2CO_3$ to be 225 and 109.2 respectively. The resistance of the cell full of KOH is 26450 ohms, then the resistance of the cell full of $\frac{1}{2}K_2CO_3$ is $225/109.2 \times 26450$ or 54513 ohms. For zero concentration of carbon dioxide the conductance of the cell is given by 1/26450, and for a concentration of .782 per cent the conductance is 1/54513. Intermediate concentrations will be proportional to the change in the reciprocal of the resistance.

EXPERIMENTAL PROCEDURE

Wheat [3] of the Marquis variety was selected for this work. It grows well in nutrient solutions, and by the use of such a medium a more accurate control of the nutritional phases of the work can be obtained. The nutrient solution used and the general cultural methods have been described in a previous publication.[4] The wheat was germinated between layers of moist filter paper in a covered glass dish at a temperature of 25° C. When the roots had grown to a length of 2 to 4 cm the young plants were transferred to a germination net stretched over a glass dish through which tap water flowed. The plants were illuminated by a 200-watt Mazda lamp placed 30 cm above the netting. When the seedlings were approximately 4 to 5 cm in length, four individuals selected for uniformity of size were transferred to the growth chamber. The plants were supported by means of cotton in the four small holes in a paraffined flat cork stopper which fitted into the lower end of the tubular growth chamber. The growth chamber was then placed over the Erlenmeyer flask containing the nutrient solution and held in place by means of a rubber annulus.

From the work of Johnston [5] with tomato plants grown under Mazda lamps it appears that the large proportion of infra-red radiation found in this type of illumination is somewhat injurious. More nearly normal growth and physiological response were obtained where heat absorbing filters were used. Nearly normal wheat plants were produced when the excessive infra-red radiation from the lamps was absorbed by a solution of copper sulphate. This was easily accomplished by using a solution of copper sulphate (1.046 sp. gr.) in place of water in the circulating system for controlling the temperature of the growth chamber. Plate 2 shows four wheat plants grown in the growth chamber for a period of 20 days.

In the following tables the light intensities are expressed in arbitrary units, and the carbon dioxide concentrations and assimilation rates expressed as changes in the reciprocal of the resistance of the conductivity cell. To express the concentration in terms of volume

[3] The wheat used in these experiments was obtained through the courtesy of H. H. McKinney, Jr., of the United States Department of Agriculture.

[4] Johnston, Earl S., The functions of radiation in the physiology of plants. II. Some effects of near infra-red radiation on plants. Smithsonian Misc. Coll., vol. 87, no. 14, pp. 1-15, 1932.

[5] Idem.

percentage the results should be multiplied by .000041, the calibration constant of the instrument. To express the assimilation rate in cubic centimeters of carbon dioxide per minute the results should be multiplied by 0.025, *i. e.*, 0.000041 × 600.

Two experiments were performed. In the preliminary one certain difficulties were encountered which suggested the procedure followed in the second experiment. A number of points of interest, however,

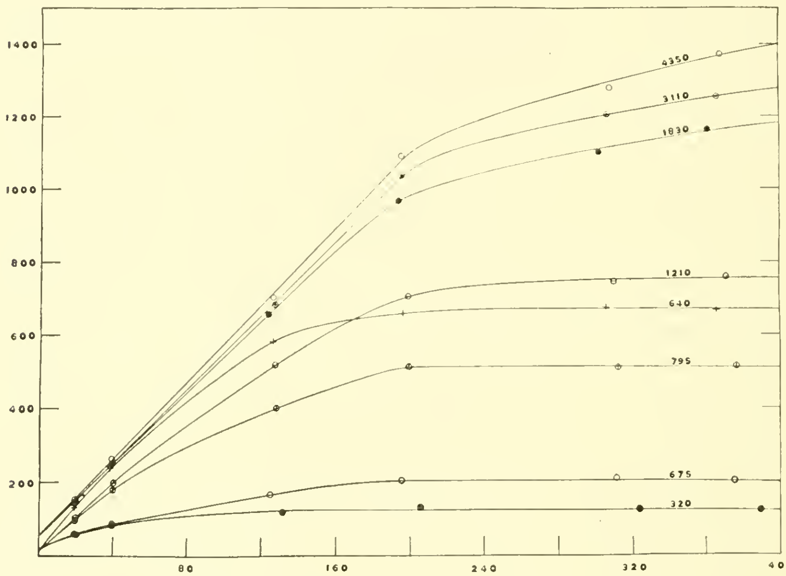


FIG. 3.—Light-assimilation curves from first experiment uncorrected for growth.
Ordinates, carbon dioxide assimilated. Multiply by 0.025 to obtain cubic centimeters per minute.
Abscissas, light intensity. Multiply by 3.56×10^{-4} to obtain watts/cm^2. Multiply by 4.96 to obtain foot-candles.
Parameters, carbon dioxide concentrations. Multiply by 0.000041 to obtain volume per cent.

brought out in the first experiment make it worth while to present both experiments.

PRELIMINARY EXPERIMENT

On a given day the plants were supplied with air containing a given concentration of carbon dioxide and the rate of photosynthesis determined for six light intensities. This procedure was repeated on other days for different concentrations of carbon dioxide. The results of this series of experiments for several concentrations are given numerically in Table 1 and graphically in Figure 3.

TABLE 1. *Assimilation data from first experiment*[a]

Light intensity variable; carbon dioxide concentration the parameter; temperature 19° C., relative humidity 74 per cent.

CO_2 concentration of air supply	Light intensity	Assimilation	Corrected assimilation	Growth factor	Corrected assimilation divided by growth factor
882	19.0	57	42	1.00	42
	39.8	85	70	1.00	70
	124.7	164	149	1.00	149
	195.0	202	187	1.00	187
	311.4	206	191	1.00	191
	375.1	206	191	1.00	191
444	20.5	58	43	1.25	34
	41.3	83	68	1.25	54
	131.1	118	103	1.25	82
	205.8	131	116	1.25	93
	323.5	125	110	1.25	88
	389.2	125	110	1.25	88
1308	19.3	96	81	2.20	37
	39.2	175	160	2.20	73
	127.1	397	382	2.20	174
	199.2	510	495	2.20	225
	312.1	508	493	2.20	224
	376.2	512	497	2.20	226
1970	19.5	102	87	2.23	39
	39.8	199	184	2.23	85
	126.6	515	500	2.23	224
	198.6	702	687	2.23	308
	310.4	742	727	2.23	326
	371.0	757	742	2.23	333
2993	19.5	147	97	2.41	40
	39.1	247	197	2.41	82
	123.0	653	603	2.41	251
	193.2	967	917	2.41	380
	302.1	1101	1051	2.41	437
	361.5	1165	1115	2.41	463
4364	19.9	145	95	2.49	39
	39.7	251	201	2.49	81
	126.1	681	631	2.49	253
	196.7	1036	986	2.49	396
	306.6	1205	1155	2.49	463
	366.1	1256	1206	2.49	483
5722	19.1	151	101	2.64	39
	38.3	260	210	2.64	80
	125.9	700	650	2.64	248
	196.6	1089	1039	2.64	397
	307.9	1278	1228	2.64	468
	368.0	1371	1321	2.64	504
1307	19.0	130	115	3.61	32
	38.1	235	220	3.61	61
	125.2	570	565	3.61	156
	195.5	657	642	3.61	178
	306.2	671	656	3.61	182
	366.0	667	652	3.61	180

[a] Conversion factors:

Carbon dioxide concentration. Multiply by 0.000041 to obtain volume per cent.

Light intensity. Multiply by 3.56×10^{-4} to obtain watts/cm^2. Multiply by 4.96 to obtain foot-candles.

Carbon dioxide assimilated. Multiply by 0.025 to obtain cubic centimeters per minute.

The data, without correction for growth, are plotted in Figure 3. An extrapolation of the curves in this figure indicate a small apparent assimilation rate for zero light intensity. This may be explained by a leakage of carbon dioxide into the apparatus through the rubber tubing which constituted part of the air line in this first experiment. This trouble was eliminated in later experiments by making a practically all-vitreous air system.

We had hoped to determine the growth curve of the plants from respiration measurements, but the changes in concentration of carbon dioxide in the air due to respiration proved to be too small to give accurate results. An approximate curve was obtained from the daily measurements of leaf lengths. The interpretation of these curves will be discussed in connection with the second experiment.

SECOND EXPERIMENT

In this experiment the order of procedure was reversed. The light intensity was held constant and the assimilation rate on a given day determined for several different carbon dioxide concentrations. This was repeated for five other light intensities. The data for this series of experiments are given in Table 2 and Figures 7 and 8. Thus we obtain immediately curves showing the assimilation rate as a function of the carbon dioxide concentration for six light intensities (fig. 7). The data for Figure 8 are derived from Figure 7. The curves in this figure show the assimilation rate as a function of the light intensity for several concentrations of carbon dioxide.

In the second experiment the rubber connections were eliminated by construction of a practically all-vitreous system. The growth curve for this experiment was determined in a manner somewhat similar to that employed by Van den Honert. The assimilation rate of the plants was measured under the same conditions, twice each day, and a linear growth relation assumed for the intervening time.

DISCUSSION OF RESULTS

In order to compare the curves of the first experiment with those of the second experiment growth correction must be applied to the data of Figure 3. Applying arbitrary growth factors which will bring the two sets of curves into harmony after making the zero correction for leakage, we obtain Figure 4. These arbitrary growth factors are plotted in Figure 5 and are shown by the solid curve. It is interesting to compare this curve with the curve for total leaf length indicated by the dotted line and those obtained from the respiration measurements shown by the broken line. It must be borne in mind that the

Table 2. *Assimilation data from second experiment* [a]

Carbon dioxide concentration variable; light intensity the parameter; temperature 22° C., relative humidity 79 per cent.

Light intensity	CO_2 concentration	Assimilation	Growth factor	Assimilation divided by growth factor
175	2902	621	1.00	621
	1793	580	1.05	552
	957	504	1.32	382
	745	433	1.35	321
	622	355	1.38	257
	283	169	1.40	121
	7525	881	1.42	621
	7031	945	1.51	625
	5191	957	1.54	620
	4064	984	1.60	615
	3078	1009	1.62	622
191	7826	1293	1.85	699
	4823	1273	1.87	682
	5277	1313	1.88	700
	4371	1314	1.89	697
	7812	1485	2.12	700
	3394	1493	2.14	698
	2425	1383	2.16	640
	1806	1287	2.18	590
	1010	1015	2.45	415
	512	549	2.47	236
127	6390	1175	2.49	472
	9657	1358	2.88	472
	6977	1326	2.90	457
	5552	1329	2.92	455
	4013	1328	2.93	453
	2772	1330	2.93	452
	7412	1479	3.24	457
	4146	1497	3.25	461
	2102	1519	3.26	465
	981	948	3.27	290
	223	358	3.28	109
	1706	1370	3.29	415
	500	726	3.30	220
80.4	10418	1010	3.32	304
	9655	1062	3.50	304
	7079	1057	3.52	301
	5173	1046	3.53	296
	3569	1077	3.54	304
	2505	1061	3.55	299
	10984	1123	3.70	304
	2004	1099	3.72	296
	1506	1017	3.73	273
	1030	860	3.74	230
	687	650	3.75	173
	350	508	3.76	135
	200	308	3.77	82
31.5	9876	455	3.95	115
	5094	460	3.96	116
	2558	450	3.97	113
	1267	439	3.98	110
	855	319	3.99	80
	300	240	4.00	60
	150	161	4.01	40
16.2	10569	252	4.20	60
	3020	260	4.21	62
	1223	250	4.22	59
	808	214	4.23	50
	400	148	4.24	35
	150	85	4.25	20

[a] Conversion factors:
Light intensity. Multiply by 3.56×10^{-4} to obtain watts/cm². Multiply by 4.96 to obtain foot-candles.
Carbon dioxide concentration. Multiply by 0.000041 to obtain volume per cent.
Carbon dioxide assimilated. Multiply by 0.025 to obtain cubic centimeters per minute.

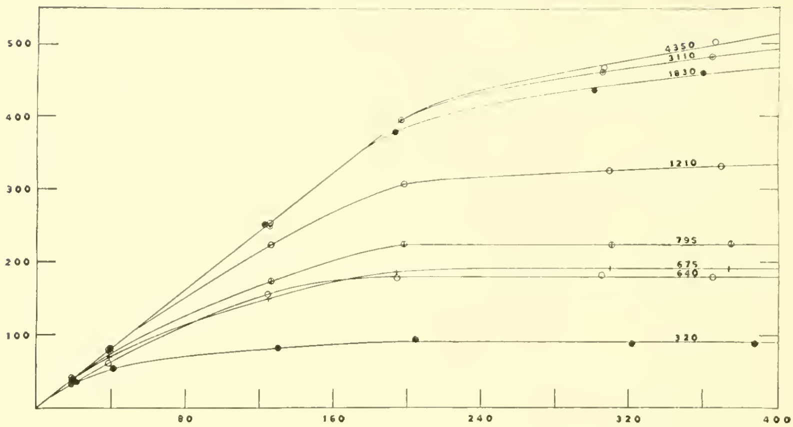


FIG. 4.—Light-assimilation curves from first experiment corrected by arbitrary growth factors.

Ordinates, carbon dioxide assimilated. Multiply by 0.025 to obtain cubic centimeters per minute.

Abscissas, light intensity. Multiply by 3.56×10^{-4} to obtain watts/cm^2. Multiply by 4.96 to obtain foot-candles.

Parameters, carbon dioxide concentrations. Multiply by 0.000041 to obtain volume per cent.

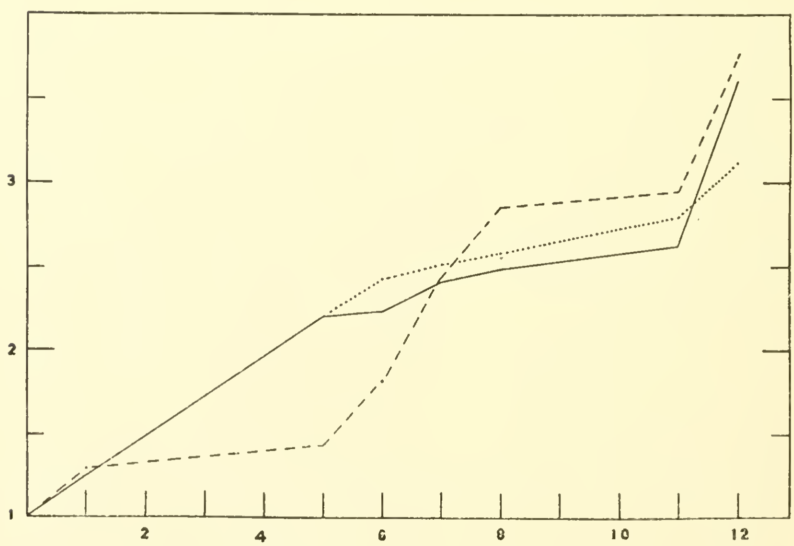


FIG. 5.—Growth factors from first experiment.

—— Arbitrary factors applied to Figure 3.
.... Factors obtained from leaf measurements.
– – – Factors obtained from respiration measurements.
Ordinates, numerical factors.
Abscissas, duration of experiment in days.

respiration measurements involve changes in concentration which are small compared to those of assimilation measurements. This accounts for the fact that whereas our error of observation is sufficient to account for the difference between these growth curves, it it still small when considered on the scale of the assimilation curves. The method of growth correction adopted in the second experiment being based upon assimilation under identical conditions has an accuracy of the same order as the assimilation measurements themselves. Thus the arbitrary factor involved in the interpretation of the first experiment is wholly eliminated in the second.

The first set of curves are interesting, however, first, because they show observations made over a wider range of light intensities, and, second, because although made in a completely different order of sequences in time, they are in complete agreement. If any marked effects of day and night or age were present, such agreement would not be possible even through arbitrary growth correction.

In order to further compare the results of the first experiment with those of the second, curves have been derived from the corrected data (fig. 4) showing carbon dioxide assimilation as a function of carbon dioxide concentration with light intensities as parameters. These are shown in Figure 6.

Directly from the second experiment we obtain assimilation rate as a function of carbon dioxide concentration for six light intensities as given in Figure 7. In the main points the two experiments are in reasonably good agreement, remembering of course that different plants have been used so that the assimilation values are not directly comparable. For the highest light intensity, 191 (fig. 7), we see that the assimilation rate is proportional to the carbon dioxide concentration from 0 to about 850. The maximum rate is not reached until the concentration has been increased to about 3,500. A further increase in the concentration produces no change in the assimilation rate. As the light intensity is decreased the departure from the linear relation occurs at a lower and lower carbon dioxide concentration. The maximum assimilation rate is less and the maximum is reached at a lower carbon dioxide concentration. In Figure 8 we see, for a carbon dioxide concentration of 3,500 or more, that the assimilation rate is proportional to the light intensity from 0 to the highest intensity used. As the concentration is decreased the departure from the linear relation occurs at a lower and lower light intensity. For small carbon dioxide concentrations a maximum rate of photosynthesis is reached for the light intensities used in this experiment. A further increase in intensity produces no change in the assimilation

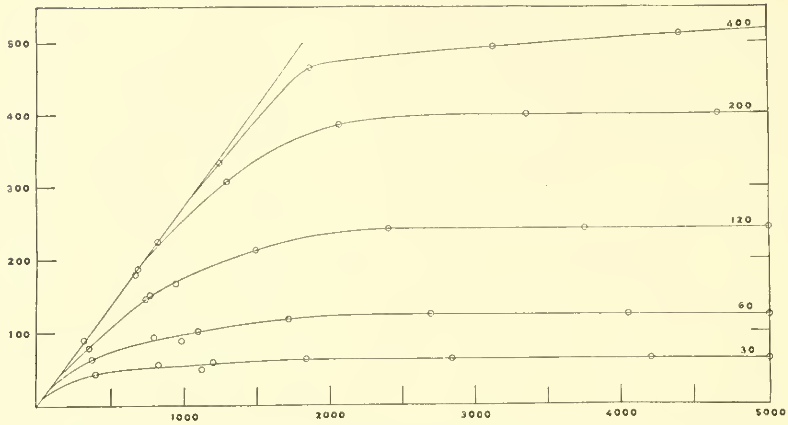


Fig. 6.—Carbon dioxide-assimilation curves derived from Figure 4.

Ordinates, carbon dioxide assimilated. Multiply by 0.025 to obtain cubic centimeters per minute.

Abscissas, carbon dioxide concentration. Multiply by 0.000041 to obtain volume per cent.

Parameters, light intensities. Multiply by 3.56×10^{-4} to obtain watts/cm^2. Multiply by 4.96 to obtain foot-candles.

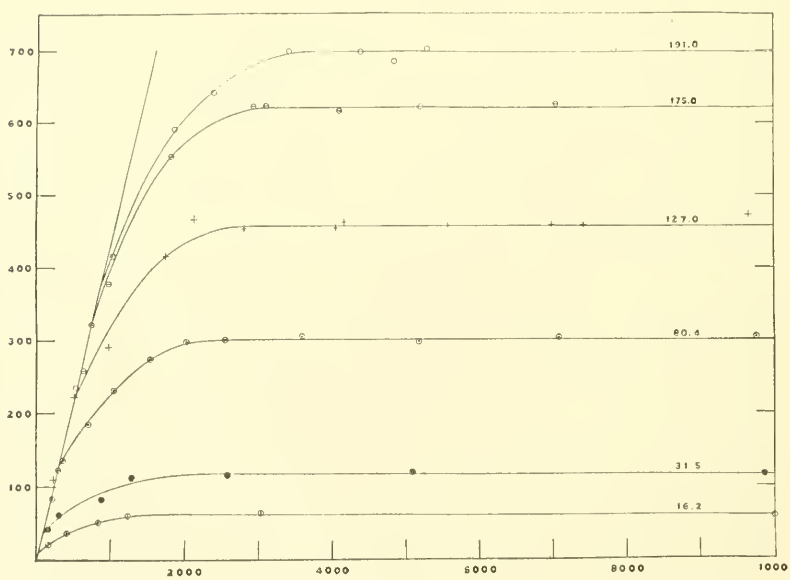


Fig. 7.—Carbon dioxide-assimilation curves from second experiment.

Ordinates, carbon dioxide assimilated. Multiply by 0.025 to obtain cubic centimeters per minute.

Abscissas, carbon dioxide concentration. Multiply by 0.000041 to obtain volume per cent.

Parameters, light intensities. Multiply by 3.56×10^{-4} to obtain watts/cm^2. Multiply by 4.96 to obtain foot-candles.

rate. It thus appears, for the condition of this experiment, that carbon dioxide may be the limiting factor for the high light intensities, assimilation being proportional to the carbon dioxide concentration over a considerable range. For the high carbon dioxide concentrations, the light intensity may be the limiting factor, assimilation being proportional to the light intensity. There exist well-defined regions over which the assimilation seems to depend upon both factors.

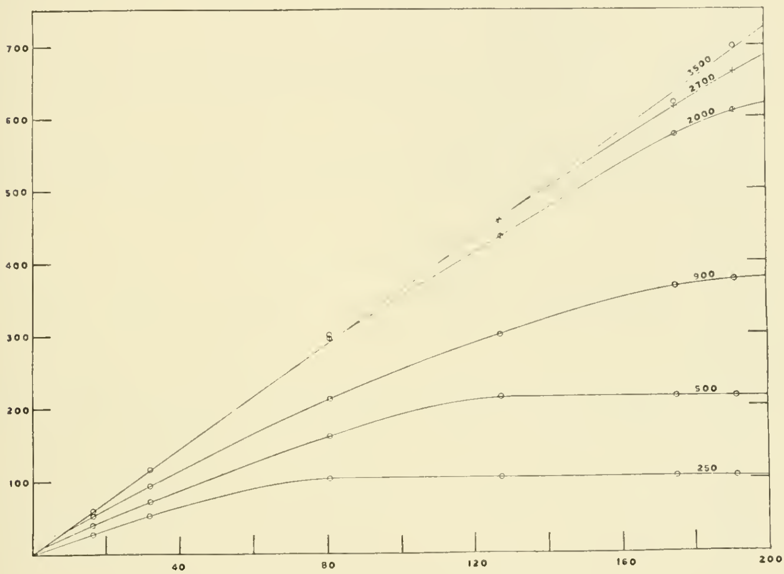


FIG. 8.—Light-assimilation curves derived from Figure 7.

Ordinates, carbon dioxide assimilated. Multiply by 0.025 to obtain cubic centimeters per minute.
Abscissas, light intensity. Multiply by 3.56×10^{-4} to obtain watts/cm^2. Multiply by 4.96 to obtain foot-candles.
Parameters, carbon dioxide concentrations. Multiply by 0.000041 to obtain volume per cent.

Assuming the simplest type of Blackman reaction involving only linear segments, some transition range is to be expected, since ideal conditions cannot be obtained. Not all the chloroplasts can be maintained in the same light intensity, nor can all the surfaces of the leaves be brought in contact with exactly the same concentration of carbon dioxide. The fact that the lights are symmetrically placed around the plants not only reduces the fluctuation of intensity over the surfaces of the leaves, but, owing to the fact that the leaves are exposed to radiation from both sides, reduces to a minimum the variations of intensity through the leaf. Rapid recirculation of the air insures a small variation in concentration of carbon dioxide over the plants.

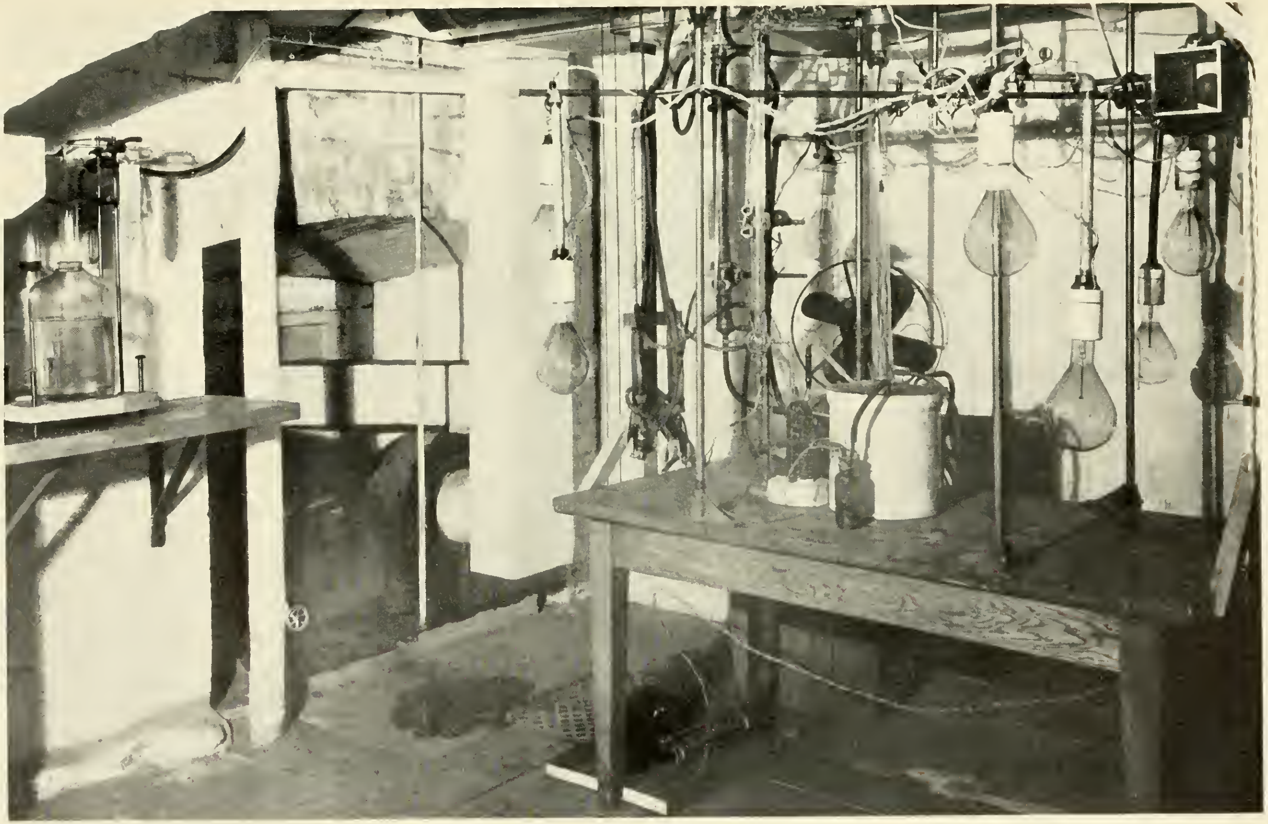
In view of these precautions, is it possible to explain the whole of the transition range as being due to variations in the environmental conditions? The actual variation of intensity over the surface of the leaves, as determined by thermocouple and photronic cell measurements, may be as much as 10 or 12 per cent from the mean values given. The chloroplasts are distributed more or less uniformly throughout the entire body of the wheat leaf; thus, there must be a considerable variation in intensity when we consider chloroplasts at different distances below the surface of the leaf. In order to get some idea of the absorption of the light in a leaf, the transmission of a wheat leaf was measured with a photronic cell, a 500-watt lamp being used as the source of light. The transmission of the leaf for the whole range to which the cell is sensitive was 18 per cent. When the radiation from the lamp was filtered through a heat-absorbing glass the transmission was reduced to 14 per cent. This is due, of course, to the regions of selective absorption. Even with the leaf illuminated from both sides it must be concluded that there is a large variation in the intensity of radiation at the surfaces of the various chloroplasts throughout the leaf. If one assumes that the whole transition range may be explained by a variation in light intensity then the variation in the intensity may be determined from Figure 8. For a concentration of carbon dioxide of about 900 we see that light is the limiting factor for a very small range. At an intensity of 10, carbon dioxide has already become the limiting factor for some of the chloroplasts. It is necessary, however, to increase the intensity to 200 or more before carbon dioxide is the limiting factor for all the chloroplasts. This would indicate that some of the chloroplasts were receiving only 5 per cent or less of the effective radiation intensity of others. It does not seem likely that the variation of intensity is so great.

Comparing these families of curves obtained from young wheat plants with those of Van den Honert obtained from algae one observes a close agreement as to general form. Both show well-defined linear variations over restricted ranges; both show transition from one linear range to the other in which the two variables affect the photosynthesis. Higher plants show a wider range of transition, as is to be expected from the fact that both light intensity and carbon dioxide concentration vary over a considerable range for different chloroplasts. Whereas light intensity has been measured with considerable accuracy in absolute terms the lack of accurate data as to leaf area and chlorophyl concentration prevents one from attaching particular significance to the slope of the linear variation.

It is evident from this discussion that such an experiment does not lend itself to an analysis of the transition range in terms of chemical kinetics. The difficulty lies entirely in the nature of the organism examined, so that further efforts in the direction of obtaining more ideal conditions and further analysis of the energy distribution, absorption characteristics, etc., would seem relatively fruitless. It remains possible, however, to make a critical attack upon many interesting problems of photosynthesis in cases where one is chiefly concerned with the range in which one or the other of the variables acts as a limiting factor. The method has the advantage of eliminating many of the objectionable factors involved in experiments where organisms are placed in abnormal growth conditions.

CONCLUSIONS

A set of families of curves has been obtained showing assimilation of carbon dioxide by young wheat plants over a wide range of carbon dioxide concentrations and light intensities. Linear variation of assimilation with carbon dioxide concentration in the presence of excess light has been observed over a limited range. Linear variation of carbon dioxide assimilation as a function of light intensity for excess carbon dioxide concentration has also been observed over a limited range. The transition range between the two regions of limiting factors is more extensive in higher plants than in algae. This may be expected from the lack of homogeneity of light intensity and carbon dioxide concentration throughout the leaf. These experiments indicate that a wide range of critical experiments upon photosynthesis may be carried out with higher plants, using the technique developed, so long as one is not particularly concerned with problems such as constants of dissociation and others particularly relating to the transition range.



Growth chamber and control equipment

Wheat plants after 20 days of growth

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 87, NUMBER 17

Roebling Fund

ABSOLUTE INTENSITIES IN THE VISIBLE AND ULTRA-VIOLET SPECTRUM OF A QUARTZ MERCURY ARC

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INTRODUCTION

For some of the biophysical investigations (1)[1] in progress at the laboratory of the Division of Radiation and Organisms of the Smithsonian Institution an absolute measure of the energy in the lines of the mercury arc spectrum was needed in greater detail than is available in the literature. This has been obtained for a common type of commercial arc (Cooper-Hewitt 220 volt D.C. quartz mercury arc), and it is believed that these results will be of interest to users of this type of mercury lamp. Although this source is not ideal from a spectroscopic standpoint the present measurements cover a wide spectral range and are accurate enough to show a smooth and regular decay in the sharp and diffuse series. Also it is found that the theoretical intensity relation for these triplets is approached by higher members of the series.

A preliminary report of these measurements was presented at a meeting of the American Physical Society (2) and the preliminary curves—uncorrected for instrumental transmission—were included in the Report of the Secretary of the Smithsonian Institution for the year ending June 30, 1931 (p. 133). The transmission of the two monochromators used has since been determined and the spectrum remapped under steadier operating conditions, so that the data may now be presented as absolute measurements of radiant flux.

Coblentz in his extensive examination of light sources (3) used in phototherapy has given data on this type of arc. His data consists mainly of filter observations that give in absolute measure the energy distribution in the different spectral regions. In a recent paper (4) he has given relative intensities of the prominent lines in the ultra-violet. Harrison and Forbes (5) and Hulburt (6) show energy

[1] Numbers in parentheses refer to the list of literature cited, found at the end of this paper.

curves of the quartz mercury arc using an effective slit width of 200 A. and 100 A. at λ 4,000 A. respectively. Hulburt supplemented his thermopile measurements with photocell observations and obtained a smaller effective slit width. (10 A. at λ 2,500 A., 20 A. at λ 3,000 A.). The present work was done with an effective slit width of 2 A. at λ 2,300 A. which increased to 12 A. at λ 4,000 A. Since the present experimental work was completed the text " Lichtelektrische Zellen " by Simon and Suhrmann (7) has been published. In it appear energy curves of the mercury arc spectrum obtained by Suhrmann which apparently have not been published elsewhere. The resolution attained is nearly identical with the writer's, and the measurements are given as absolute. The relative intensities agree fairly well with the present work, even though the arcs were of different type. However, the absolute values disagree by more than two orders of magnitude. This will be discussed later.

EXPERIMENTAL

These measurements were made on the Cooper-Hewitt 220 volt D.C. quartz arc in the spectral region 2,100 A. to 7,000 A. Observations were taken on four " vertical " arcs and one " horizontal " arc. Two sets of measurements were made: 1, the arcs running under normal power consumption of 4.5 amperes with 150-volt drop across the arc, and 2, a low power consumption of 3.0 amperes and 44 volts. Subsequently these will be called " high intensity " and " low intensity " operating conditions respectively. Radiation from a 20-mm length of the arc midway between electrodes was measured with the monochromator and thermocouple combination, care being taken that no scattered light of any consequence was included. Filter measurements with a bare (windowless) thermocouple were taken of the radiation from this 20-mm midsection, as well as the radiation from the total arc. These filter observations provide a measure of the energy in different spectral regions with which the summation of the line intensities can be compared. Also they provide a factor that can be used—with no serious error—to reduce the line intensities for the midsection of the arc to " total arc " intensities. A bank of storage cells was used as a source of current for the low-intensity observations. A D.C. motor-generator outfit—regulated with a synchronous motor—was used for the high-intensity work. In both cases the choke coil and series resistance furnished by the manufacturer were used to steady the arc.

A single-junction vacuum thermocouple provided with a crystal quartz window and of a type described elsewhere (8) was used for the monochromator observations. A Leeds and Northrup H.S. galvanometer with a curved (circular) scale was used and calibrated for current versus deflection in the usual manner. The thermocouple galvanometer combination was calibrated in terms of a radiation standard furnished by the Bureau of Standards. By using an auxiliary windowless thermocouple and a monochromatic beam of light—λ 4,358 through the monochromator of which the window of the vacuum couple transmitted 91.0 per cent—it was determined that 86 per cent of the radiant energy from the standard of radiation was transmitted by the window of the vacuum thermocouple. The thermocouple was provided with a slit 0.10 mm wide, which is immediately in front of the receiver. The receiver is 2.8 mm high. At a distance of 2 m from the standard of radiation the flux is 64.2 microwatts per cm^2. This produced a deflection of 41.5 mm. Hence a deflection of 1.0 mm corresponds to an intensity of 1.33 microwatts per cm^2 on the receiver. For the bare thermocouple a deflection of 1.0 mm corresponds to an intensity of 8.51 microwatts per cm^2.

For dispersion two Bausch & Lomb quartz monochromators were used, both singly and in tandem as a double monochromator. When used singly the exit slit of the monochromator was removed and replaced by the thermocouple which is provided with a slit. When the two were used in tandem the curved exit slit of the first monochromator served as the entrant slit of the second. This arrangement straightens out the image falling on the thermocouple and improves the resolution. The two were maintained in permanent alignment on a cast-iron table with seats provided for the leveling screws of the monochromators. A special sleeve held the collimator of the second instrument in proper position with respect to the telescope of the first. The use of two instruments greatly reduces the scattered light which in an instrument of numerical aperture f4 is to a certain extent inevitable. The source to be examined was rigidly attached to the cast-iron table so that no change in illumination could occur during a series of observations. The length of the entrant slit was reduced to 2.75 mm by two knife edges and the arc placed 250 mm from it. No condensing lens was used. Since the section of the arc exposed was nearly square the illumination produced at the collimator lens of the monochromator was square in form and covered about one half the area of the aperture. The corners of the square were well inside the circle limiting the aperture, the illumination being observed by placing the eye at the exit slit with an intervening screen to reduce the intensity. In measuring the absolute intensities of isolated spectral lines a single monochromator with a 0.10-mm slit was used. To obtain the greater resolution required for close groups and reduce the effect of scattered light the double monochromator set-up was used with a 0.05-mm slit.

The transmission of the monochromators for the wave lengths used was obtained with the aid of a photronic cell provided with a quartz window. This was used instead of a thermocouple because its characteristics render it relatively insensitive to a change in position behind the monochromator. For a constant amount of incident energy the cell's response is practically independent of the area exposed. One of the vertical arcs operating at high intensity was used for this calibration. It was placed 250 mm from the slit so as to give an illumination identical with that used in the intensity measurements. Another photronic cell connected to a microammeter was placed so as to receive total radiation from the arc. This microammeter, which indicated the output of the arc, and a voltmeter and ammeter measuring the input were mounted near the galvanometer scale so that the observer could glance at them before taking a reading. For both the transmission measurements and the intensity measurements galvanometer readings were taken only when this photronic cell indicated the same output from the arc. The intensity of 19 of the stronger lines was observed at the exit slit of one monochromator. Then the second instrument was placed in tandem and readings taken on the same lines. The ratio of the latter reading to the former for a particular wave length is the transmission of the second monochromator for that wave length. The positions of the instruments were then reversed and the process repeated. The transmissions so obtained were plotted and smooth curves drawn. Points taken from the smooth curve for the instrument used in the intensity measurements are included in Table 1. The transmission of one instrument differed by less than 1 per cent (*i. e.*, 46 per cent compared with 47 per cent) from that of the other and was consistently higher. The transmission of either machine with the field illuminated as stated was several (2 to 4) per cent higher than that given by the manufacturer. This difference is probably due entirely to the difference in illumination, as the manufacturer's figures are for a completely filled aperture.

Measurements were made with a bare thermocouple of the energy in the spectral regions transmitted by the following filters—taken in the order given: 1, no filter (all wave lengths); 2, rock salt (all wave lengths up to 19μ); 3, fused quartz water cell (all wave lengths up to 1.4μ with a slight diminishing of the deep ultra-violet below 2,500 A.); 4, filter No. 3 plus barium flint glass (wave lengths below

3,200 A. excluded). These wave-length limits are only approximate because the filters do not have a sharp "cut-off." There is a region of 200-300 A. in which the change from opaqueness to transparency takes place. A typical change is seen in Table 1, column 4, which is

Table 1. *Instrumental constants*

1 Wave length (A.)	2 Transmission of monochromator	3 Transmission of thermocouple window	4 Amount excluded by barium flint and transmitted by fused quartz water cell
6908	0.520	0.918	0.00
6234	.507	.917	.00
5780	.499	.916	.00
5461	.493	.915	.00
4916	.485	.912	.00
4358	.474	.910	.00
4047	.468	.905	.008
3906	.466	.904	.014
3654	.461	.902	.030
3341	.456	.900	.405
3130	.452	.900	.894
3022	.450	.900	.90
2967	.449	.900	.89
2925	.448	.899	.88
2894	.448	.898	.88
2804	.445	.897	.88
2752	.443	.897	.88
2699	.442	.896	.88
2652	.440	.895	.88
2602	.438	.895	.85
2576	.436	.895	.80
2536	.434	.894	.76
2483	.431	.894	.69
2463	.430	.894	.69
2447	.429	.893	.68
2399	.426	.892	.67
2378	.425	.892	.64
2352	.422	.891	.60
2323	.420	.891	.58
2300	.418	.890	.57
2283	.416	.890	.55
2250	.413	.890	.51

the difference—transmission of fused quartz water cell minus the transmission of the barium flint filter. A series of four diaphragms was used to exclude radiation other than that coming directly from the arc. The results of these measurements are given in Table 3. They are compared with the summation of the monochromator measurements and correlated with the measurements of other observers in the discussion.

RESULTS AND DISCUSSION

Using the double monochromator—with the entrant slit set at 0.05 mm and the middle slit 0.075 mm—and the vacuum thermocouple, the high-intensity spectrum was mapped by taking readings one slit width apart throughout. The arc was operated at 4.5 amperes and an average of 143.5 volts.

In the region	7,000 to 6,000 A.	readings were taken every	50 A.,
	6,000 to 5,000 A.	" " " "	25 A.,
	5,000 to 4,000 A.	" " " "	20 A.,
	4,000 to 3,500 A.	" " " "	10 A.,
	3,500 to 2,500 A.	" " " "	5 A.,
	2,500 to 2,100 A.	" " " "	2.5 A.

Readings were also taken at the peaks of the maxima. This gave a map of the spectrum of the highest resolution attainable with the setup. Fifty maxima many of which are complex were observed. Then a single monochromator was used with 0.10-mm slit, and readings were taken on 32 of the stronger lines. The intensities obtained with the double monochromator were then corrected slightly where necessary so that they agreed with the more accurate values obtained with the single monochromator. The arc was then operated at low intensity and observations were made with the single monochromator. The galvanometer deflections were read with a telescope. These data are given in Table 2. Columns 2 and 3 are the galvanometer deflections for the same arc run at high and low intensity respectively. This arc had been used about 400 hours. These deflections were reduced to absolute intensities by multiplying by 1.33 (microwatts per cm^2 for 1 mm deflection) and dividing by the product of corresponding values for the transmission of the monochromator and of the thermocouple window given in Table 1, columns 2 and 3. These intensities are given in Table 2, columns 4 and 6, and are in microwatts per cm^2 for a distance of 250 mm from the center of the arc and on the perpendicular bisector of a line from the cathode to the mercury pool. The values in Table 2, columns 7 and 8, show the amount of flux excluded by the barium flint and transmitted by the fused quartz water cell. These values are obtained by multiplying the absolute intensities in Table 2, columns 4 and 6, by corresponding values in Table 1, column 4. The sums at the bottom of columns 4, 6, 7, and 8 in Table 2 are for comparison with the filter observations.

The sum of the intensities of all the lines of wave length less than and including λ 3,130 is of interest, as it is this part of the radiation from the mercury arc that is useful in curing rickets and produces

TABLE 2. *Monochromator measurements of high and low intensity arcs*

1 Wave length (A.)	2 Galvanometer reading (mm) High int.	3 Low int.	4 Absolute intensity 250 mm from a 20-mm midsection of the arc (mcw cm^{-2}) High int.	5 High int. new arc	6 Low int.	7 Amount excluded by barium flint and transmitted by quartz water cell (mcw cm^{-2}) High int.	8 Low int.
6908	2.7	0.06	7.5	....	0.17	0.0	0.0
6234	0.9	.03	2.6	....	0.09	.0	.0
5780	161	3.73	468	473	10.85	.0	.0
5461	130	9.05	384	384	26.70	.0	.0
4916	4.5	.03	13.5	....	.09	.0	.0
4358	106	7.90	327	353	24.40	.0	.0
4047	62	4.80	195	204	15.10	1.5	.12
3906	2.6	.04	8.2	....	.13	.1	.00
3654	183	5.50	585	643	17.60	17.6	.53
3341	16	.36	52	54	1.17	3.4	.47
3130	110	5.10	359	377	16.70	321	14.92
3022	57	1.16	187	194	3.82	168	3.44
2967	29.5	1.05	97.1	95.1	3.46	86.5	3.08
2925	4.0	.11	13.2	....	.36	11.6	.32
2894	10.7	.33	35.4	34.7	1.09	31.2	.96
2804	22.4	.44	74.7	71.7	1.47	65.9	1.29
2752	7.0	.18	23.4	....	.60	20.6	.53
2699	9.5	.16	31.9	....	.54	28.1	.48
2652	40.5	.86	137	130	2.91	121	2.56
2602	2.7	.04	9.2	....	.14	7.8	.12
2576	5.4	.07	18.4	....	.24	14.7	.19
2536	52	4.73	178	154	16.20	136	12.30
2483	15.8	.44	54.6	48.6	1.52	37.8	1.05
2463	2.1	.06	7.3	....	.21	5.0	.15
2447	1.8	.03	6.3	....	.10	4.3	.07
2399	5.8	.14	20.3	23.3	.49	13.6	.33
2378	4.9	.11	17.2	22.6	.39	11.0	.25
2352	4.5	.07	15.9	16.7	.25	9.6	.15
2323	1.8	.03	6.4	....	.11	3.7	.06
2300	1.4	.06	5.0	....	.21	2.9	.12
2283	0.9	.04	3.2	....	.14	1.8	.08
2250	0.7	...	2.6	....	....	1.3	....
Total for 143.5 volts			3,302.3		147.3	1,126	43.6
Total corrected to 150 volts			3,450			1,180	
Total less than and including λ 3,130 for 143.5 volts			1,303		51.0		
Total less than and includ- λ 3,130 (corrected to 150 volts)			1,362				

For "total arc" multiply all values by 7.1

"sunburn" or erythema (4). The percentage of the total radiation which falls in this region is shown in Table 3.

Measurements were made on the more prominent lines in the spectrum of a new arc. These are shown in Table 2, column 5. The differences between these values and those in column 4 are not large but are greater than experimental error and probably indicate the variation to be expected.

Observations were also made upon two new arcs operating at low intensity. These two arcs are to be used only as standards, and since there is very little evaporation of the tungsten cathode or deterioration of the quartz at this temperature and wattage, they have never been run at any condition other than that of low intensity. Their output is different (by an amount greater than experimental error) from that of the 400-hour-old arc only in the 2,536 A. region. In this region one arc is 7.6 per cent lower and the other 2.7 per cent higher than the value given in Table 2, column 6.

Figure 1 is a map of the high-intensity spectrum obtained with the double monochromator. The effective slit width used is 2 A. at λ 2,300 A. which increased to 12 A. at λ 4,000 A. The intensities are mapped above a spectrogram (taken with a type E2 Hilger quartz spectrograph) of the arc operating at high intensity. The ordinates in Figure 1 are the values given in Table 2, column 4, and are for the 20-mm midsection of the arc. In order to obtain approximate values for the full length of the arc exposed, multiply these midsection values by 7.1. This factor is obtained from the filter measurements given in Table 3.

Figure 2 is a map of the low-intensity spectrum made from Table 2, column 6. It is plotted above a low-intensity spectrogram of the same source. The same factor, 7.1, will convert these ordinates and the values in Table 2, column 6, to approximate total arc values.

Figure 3 shows two microphotometer curves of spectrograms of the 2,536 A. region. The upper curve is from a high-intensity spectrogram and the lower curve from one of low intensity. The exposure times were 20 seconds for the low intensity and 1 second for the high intensity. For the sake of comparison the slit width used in the thermocouple observations is indicated. The resonance line, λ 2,536.5 A., which is partially self reversed at low-intensity conditions and completely reversed at high intensity, the line λ 2,534.8 A. and a background of continuous (and band?) spectrum are superimposed when observed with this 5 A. slit width. The reversal of the resonance line and the appearance of the background near it are more critical functions of the operating conditions and of the presence of small amounts of foreign gases than are the intensities of the rest

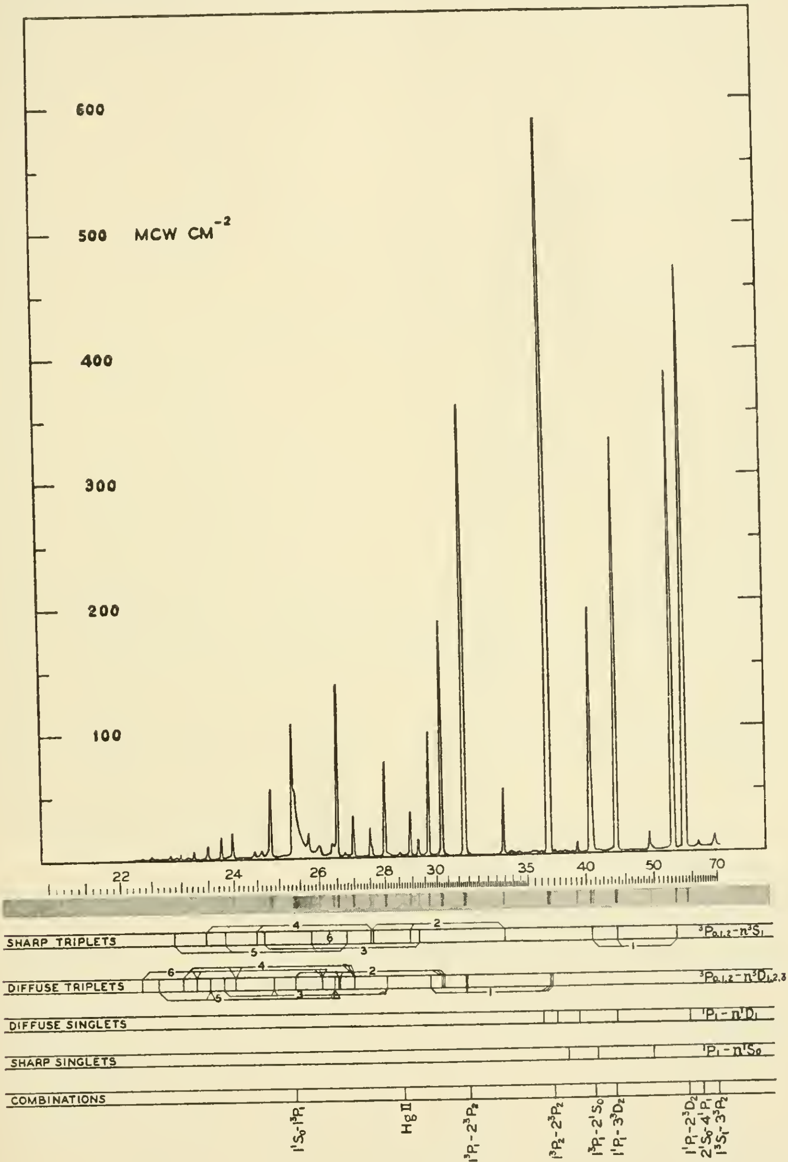

FIG. 1.—Absolute intensities 250 mm from a 20 mm mid-section of the "high intensity" arc.

of the spectrum. Hence in a commercial product one would expect such a variation as is observed in comparing one arc with another.

It is evident from these curves that the intensity in the 2,536 A. region as measured by the thermocouple is largely due to the resonance

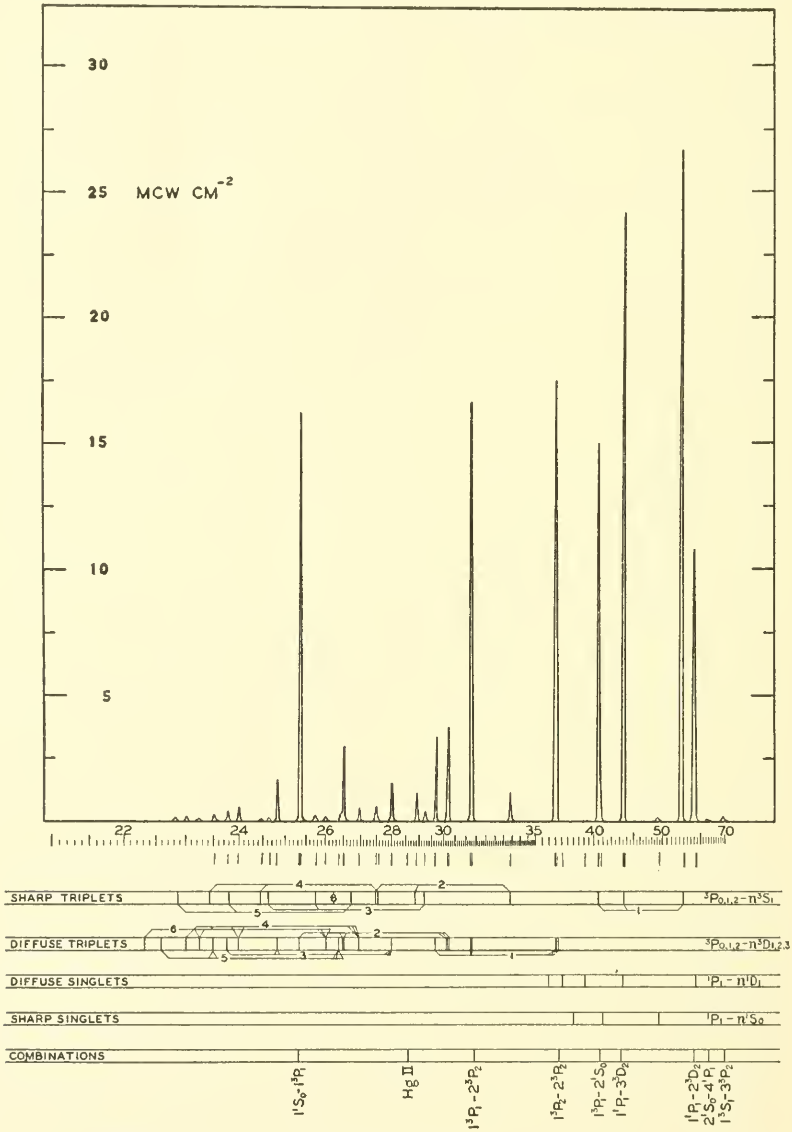

FIG. 2.—Absolute intensities 250 mm from a 20 mm mid-section of the "low intensity" arc.

line in the low-intensity arc, while λ 2,534.8 and the background are practically all that affect the thermocouple in the high-intensity arc.

Table 3 gives the intensities of radiation in the different spectral regions for a distance of 1 m from the arc. They are expressed in

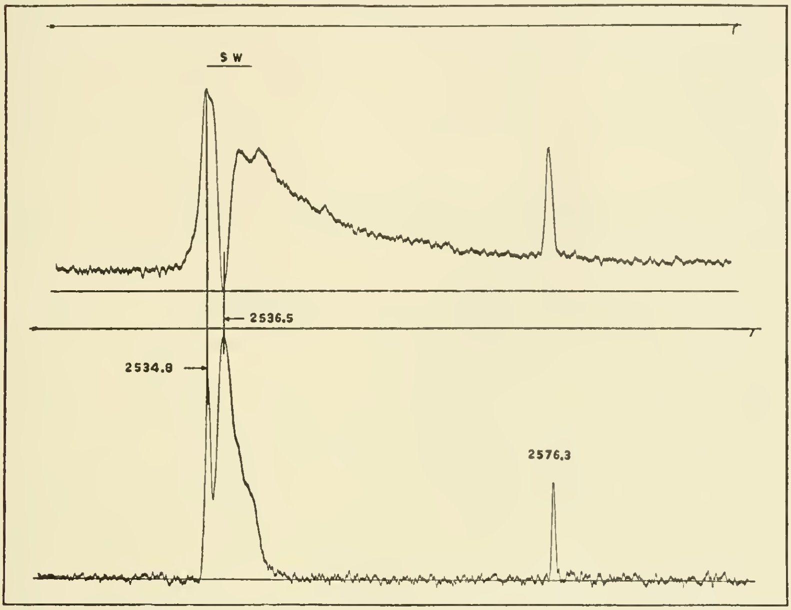

FIG. 3.—Microphotometer curves of spectrograms of the 2,536 A. region for the "high" and "low intensity" arcs.

microwatts per cm². Column 1 shows the intensity of the therapeutic (4) radiation .2μ to .35μ, column 2 the near ultra-violet, visible, and

TABLE 3. *Filter measurements*

		1 .2-.35μ	2 .35-1.4μ	3 1.4-19μ	4 >19μ	5 Total
HIGH INTENSITY						
20 mm of vertical arc...	mcw cm⁻²	84	167	245	68	564
	per cent	14.8	29.7	43.4	12.1	100
Total vertical arc......	mcw cm⁻²	600	1,130	2,710	350	4,790
	per cent	12.5	23.6	56.6	7.3	100
Total horizontal arc....	mcw cm⁻²	615	995	2,700	370	4,680
	per cent	13.2	21.2	57.7	7.9	100
LOW INTENSITY						
20 mm of vertical arc...	mcw cm⁻²	2.8	7.7	77.5	8.0	96
	per cent	3.0	8.0	81.7	8.3	100
Total vertical arc......	mcw cm⁻²	19.8	59.6	704.8	124	908
	per cent	2.3	6.6	77.6	13.5	100

near infra-red .35μ to 1.4μ, column 3 the infra-red from 1.4μ to 19μ, column 4 the deep infra-red beyond 19μ, and column 5 the total radiation. The percentage of the total radiation is given immediately below each intensity value. Observations were made on the radiation from the 20-mm length of the midsection as well as from the total length of the arc for both high and low intensities. The data given in the table were obtained using a bare thermocouple, the procedure being as follows: Observations were made on: 1, the total radiation —no filter used; 2, radiation transmitted by 2 mm of rock salt, which includes all wave lengths less than 19μ; 3, radiation transmitted by a fused quartz water cell, all wave lengths below 1.4μ, and 4, radiation transmitted by a combination of the water cell and 2 mm of barium flint glass which includes all wave lengths between $.35\mu$ and 1.4μ. These observations were then corrected for reflection and absorption by the following transmission factors: rock salt 0.91, water cell 0.90, water cell and barium flint 0.81. After these corrections are applied the data in Table 3 are obtained as follows: values in column 1 are the difference between observation 3 and observation 4; column 2, observation 4; column 3, observation 2 minus observation 3; column 4, observation 1 minus observation 2; and in column 5, observation 1. As the filter "cut-offs" are not sharp, appreciable error might be introduced by this method. For instance the short wave length "cut-off" for the barium flint filter is not sharp. However, in the mercury spectrum this is not serious because the "cut-off" occurs in a region where there are no strong lines. The sum of the monochromator values for all wave lengths less than and including λ 3,130 A. for the 20-mm midsection of the high-intensity arc is given at the bottom of Table 2, column 4. It is 1,362 microwatts per cm^2 at 250 mm from the arc. The filter measurement for this region is given in Table 3, column 1, as 84 microwatts per cm^2 at 1 m. Multiplying this by 16 to reduce it to the intensity at 250 mm from the arc we get 1,330 microwatts per cm^2, which is 2.1 per cent lower than the monochromator sum.

For the sake of a more rigid check on the monochromator observations one may compare the intensities given in Table 2, columns 7 and 8, with the uncorrected thermocouple measurements. Table 2, columns 7 and 8, give the radiation excluded by the barium flint filter and transmitted by the fused quartz water cell for the 20-mm section of the high- and low-intensity arc. These can be compared with the filter measurements as follows: the radiation transmitted by the fused quartz water cell minus the radiation transmitted by the cell in combination with the barium flint filter, the latter value being corrected for the transmission of the barium flint alone is 1,210 microwatts per cm^2 at 250 mm from the high-intensity arc. This is

2.5 per cent higher than the monochromator value 1,180 microwatts per cm^2 given at the bottom of column 7 in Table 2. For the low-intensity arc the filter measurement is 44.8 microwatts per cm^2 at 250 mm from the arc. The monochromator value given at the bottom of column 8 in Table 2 is 43.6 microwatts per cm^2 which is 2.7 per cent lower than the filter observation. This is a fairly satisfactory agreement between the monochromator sums and the filter measurements.

From Table 3 we obtain the factor 600/84 (or 19.8/2.8) = 7.1 which can be used to reduce the intensities for the midsection of the arc to total arc intensities. This factor applies to Figures 1 and 2 and to the data in Table 2.

Coblentz (4) gives a value of 623 microwatts per cm^2 for the intensity of radiation of wave lengths less than and including λ 3,130 A. at 60 cm from a 260-watt arc of this type. Assuming his arc to be equally efficient in producing radiation in this region and neglecting the absorption of air this reduces to 582 microwatts per cm^2. This is 3 per cent lower than the value 600 microwatts per cm^2 given in Table 3. Hulburt (6) gives a value for the radiation from a 650-watt arc in the region 2,000 A. to 6,500 A. His value is given as 22.0 mm deflection (with a thermopile sensitivity of 0.97 microwatts per cm^2 for 1 mm deflection) measured at a distance of 240 cm from the arc. Of the 45 mm length of his arc, 4 mm was exposed. Assuming this 4 mm length to be typical and that the arcs are equally efficient we can reduce this to "total arc" at a distance of 25 cm to compare with the monochromator sum in Table 2 at the bottom of column 4. The calculation gives a value of 23,000 microwatts per cm^2 which is 6 per cent lower than the monochromator sum 24,500 microwatts per cm^2 (3,450 × 7.1). This agreement is better than could be expected because of the uncertainty in calculating the radiation from the "total arc" from the ratio of the total length to the length exposed. Suhrmann's measurements (7) are given as absolute but differ by two orders of magnitude from the present work. The monochromator he employed has a numerical aperture of 12.5 and the entrant slit (5 mm by 0.20 mm) was placed 25 mm from the arc. Thus probably less than 1/100 of the radiation coming through the monochromator slit passed through the collimating lens and was measured. This very likely explains his very low values.

To obtain an "overall" value of the probable errors involved in the intensity measurements given in Table 2 a hypothetical line whose intensity is the average of all the lines measured has been assumed. Although the probable error calculated for it will be somewhat too small for more intense lines and too large for very weak lines it will indicate the accuracy of the measurements. For the high-intensity values, Table 2, the average galvanometer deflection was 40 mm. The probable error of the mean of 10 readings was 0.7 mm or ± 1.4 per cent. Values in Table 1, column 3, are subject to a probable error of ± 0.5 per cent and values in column 2 to ± 2 per cent. The probable error of the value 1.33 (the thermocouple sensitivity) is ± 1.4 per cent. Hence the probable error of the mean value, 100 mcw cm^{-2}, is about 3 per cent or ± 3 mcw cm^{-2}. For the values given that are of the same order of magnitude as the probable error of the mean, ± 3 mcw cm^{-2}, the predominant error is in the galvanometer reading. Hence the probable error for these entries in Table 2, column 4, is about ± 1.5 mcw cm^{-2}. For the low-intensity values in Table 2, the average galvanometer deflection was 1.9 mm and the probable error of the mean of 10 readings was 1/20 mm, or ± 2.6 per cent. Here the deflections were read with a telescope, and the arcs output was much steadier than for the high-intensity observations. The other errors are the same so the probable error of the mean value, 4.6 mcw cm^{-2}, in Table 2, column 6, is about ± 4 per cent or .18 mcw cm^{-2}. As before the probable errors of values of this order of magnitude in Table 2, column 6, are determined by the error of reading the galvanometer; hence the probable error of these entries is about 0.12 mcw cm^{-2}. The average deviation of the values in Table 2, column 5 (new arc) from those in column 4 (arc 400 hours old) is 5.3 per cent, which is about twice the probable error. Thus it is reasonable to assume that the differences are real—especially so in the short wave length region where the new quartz is more transparent.

Figure 1 shows 50 maxima. Thirty-two of the strongest and most clearly resolved of these are included in Table 2. The intensity of the weaker lines and of the unresolved components omitted from Table 2 will be reported in the near future. A new crystal quartz spectrograph of higher dispersion now in the process of construction will be used for this work.

These absolute intensity measurements are interesting from a spectroscopic standpoint. The pressure of the mercury vapor in the high-intensity arc is about one atmosphere, and in the low-intensity arc it is several millimeters of mercury. This amount of vapor will cause considerable self reversal as is most evident for the resonance line λ 2,536.5 A. and so make difficult the comparison of experimental and theoretical intensities of related spectral lines. However, because these measurements cover a wide spectral range it is interesting to

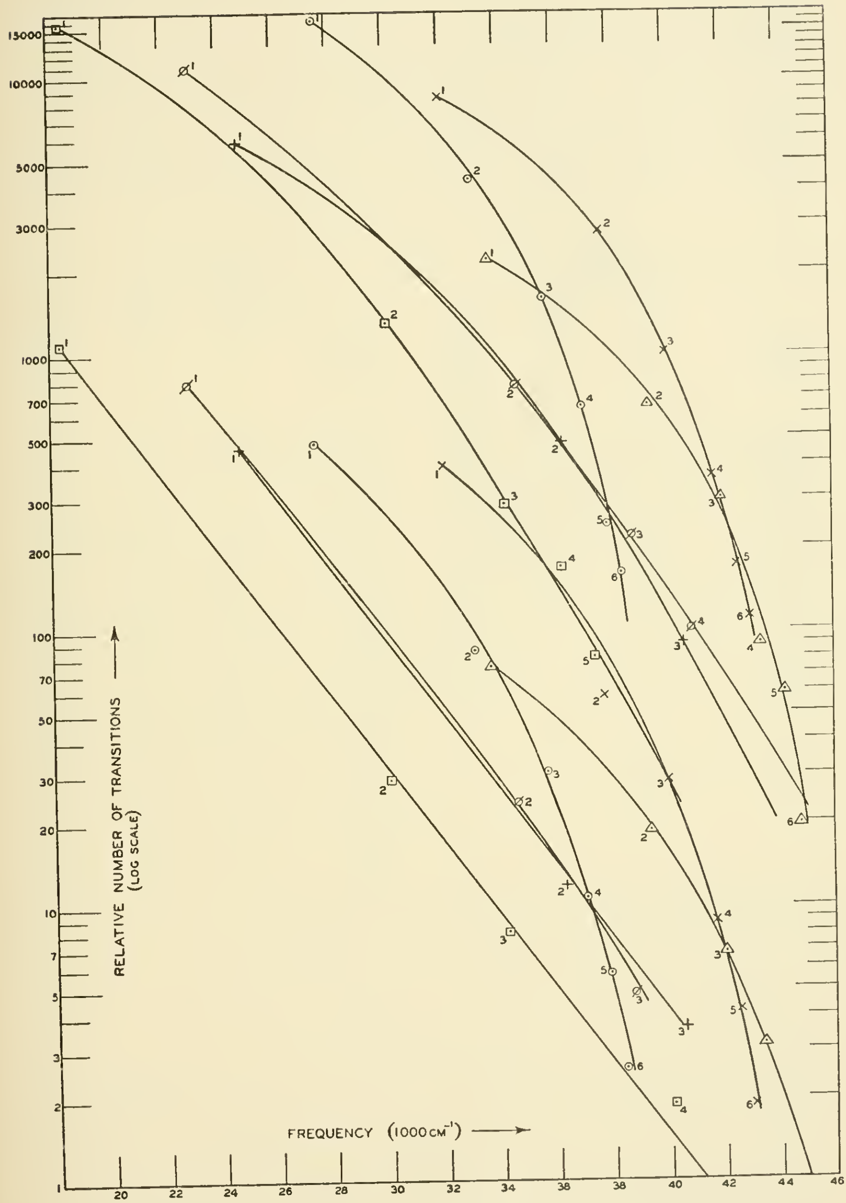

FIG. 4.—Decay of intensity in the sharp and diffuse series of Hg I.

note the decay of intensity in the sharp ($^3P_{0,1,2}$-n^3S_1) and diffuse ($^3P_{0,1,2}$-$n^3D_{1,2,3}$) series as well as the relative intensities of the components of these multiplets.

The classification of the lines measured is given below the spectrograms in Figures 1 and 2. More than two thirds of these lines are members of the sharp and diffuse series. Table 4 gives the relative intensity of these triplets that were of measurable intensity. The

TABLE 4. *Relative intensities of the multiplets*

	Sharp lines				Diffuse lines		
λ	High int. I/ν^4	Low int. I/ν^4	ν (cm^{-1})	λ	High int. I/ν^4	Low int. I/ν^4	ν (cm^{-1})
5461 ⊡ ^{1}	50	50	18308	3655 ⊙ ^{1}	50	50	27388
4358 φ ^{1}	17[a]	34[a]	22938	3130 × ^{1}	18	27	31984
4047 + ^{1}	8[a]	15[a]	24705	2967 ◬ ^{1}	4	4	33691
3341 ⊡ ^{2}	50	50	29918	3022 ⊙ ^{2}	50	50	33087
2894 φ ^{2}	19	27	34549	2652 × ^{2}	22[a]	24[a]	37696
2753 + ^{2}	10	12	36316	2535 ◬ ^{2}	..	..	39440
2925	50	50	34173	2804	50	50	35660
2576	25[a]	21[a]	38804	2480	21[a]	31[a]	40278
2464	10	13	40572	2378	6	7	42034
2760	50	..	36225	2699	50	50	37042
2447	26	..	40856	2399	19	29	41665
2345	..	..	42624	2302	4	5	43426
				2640	50[a]	50[a]	37869
				2352	21	26	42496
				2259	8	..	44257
				2603	50	50	38404
				2323	23	25	43030
				2232	..	..	44830

[a] Value given includes minor unresolved lines not related to the triplet (symbols given after wave length are those used in fig. 4).

diffuse series is really composed of sextets, but the closely spaced components were unresolved in the present work. The intensities of these groups have the same theoretical relation (1 : 3 : 5 for the Int/ν^4) as do the sharp triplets. It is evident here that the theoretical intensity relation is not attained but that it is approached by higher members of each series. The component whose intensity is most affected by changing from high intensity to low is the central one in both series. Also the component that deviates most from the theoretical rule is the central one in the sharp triplets and the high frequency one in the diffuse triplets.

Figure 4 shows the intensity decay in these series. This is a plot of the logarithm of the relative number of transitions (intensity/ν) that occur in the whole of the 20-mm section of the arc in unit time against the frequency (6). The symbols shown in Table 4 are used to identify the series and its multiple numbers. The smooth and regular decay shown here is not present in previous work and verifies the small experimental error given. The upper curves are for the high-intensity arc and the lower are for the low. The curves appear to approach asymptotic lines of the same slope in a given series. This slope is greater for the diffuse series which indicates a lower "Boltzmann" temperature for the ^3D than for the ^3S levels as was pointed out by Hulburt (6).

SUMMARY

Absolute measurements of the intensity of 32 of the more intense lines in the visible and ultra-violet spectrum of a quartz mercury arc have been made with a vacuum thermocouple and double monochromator. The effective slit width employed was 2 A. at λ 2,300 A. increasing to 12 A. λ 4,000 A. This yields a resolution about one order of magnitude greater than that of previous work of this nature. The probable error in the intensity measurements is ± 3 per cent. Observations made upon four arcs showed significant differences in intensity for many of the spectral lines. These differences averaged about 5 per cent, the maximum being 10 per cent for λ 2,537 A. This is probably the deviation in output to be expected from different arcs of this same make (operating with the same current and voltage) that are reasonably new and have not been mistreated.

About two thirds of the lines measured are members of the sharp and diffuse series. The present measurements show a smooth and regular decay of intensity in these series. The theoretical intensity relation for these multiplets is not attained but is approached by higher members of both series.

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SMITHSONIAN MISCELLANEOUS COLLECTIONS
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Roebling Fund

SUN SPOTS AND WEATHER

BY
C. G. ABBOT
Secretary, Smithsonian Institution

(PUBLICATION 3226)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
NOVEMBER 20, 1933

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I wish to present evidence pointing to four major conclusions regarding weather, as follows:

1. The principal departures from normal climates which comprise "weather" are due primarily to a group of periodic variations of the sun's radiation rather than to terrestrial complexities, as has been generally supposed.

2. Sun spots are associated with important modifications of weather not hitherto recognized.

3. Important periodicities in solar variation have their least common multiple in 23 years. As a consequence, weather repeats itself in all parts of the world with 23-year intervals. This period agrees with Hale's discovery of the double sun-spot period cycle in the magnetic condition of the sun.

4. At many stations this cycle in weather enables us to forecast general conditions of temperature and precipitation for many years in advance. Accurate seasonal predictions would require a more complete knowledge of the causes of shifts of phase in weather periodicities than is yet available.

A. ASSOCIATED SOLAR AND TERRESTRIAL PERIODICITIES

During the past year Mrs. A. M. Bond and I have been studying the departures from normal monthly temperatures for several stations in the United States. We have derived our data from "World Weather Records,"[1] and its continuation to 1930, now in galley proof at the Smithsonian Institution. In order to avoid confusion we have eliminated short-interval fluctuations by taking running 5-month means.[2] This device, of course, greatly reduces the amplitudes of the

[1] Smithsonian Misc. Coll., vol. 79, 1927.

[2] If a, b, c, d, e, f, are values, substitute for c and d $\frac{a+b+c+d+e}{5}$, $\frac{b+c+d+e+f}{5}$, etc.

periodic terms of 7- and 8-month periods. In what follows, all the modern results are derived from data thus smoothed. In the use of precipitation observations the absolute values are first converted into percentages of the monthly mean values as these are given in bold face type in "World Weather Records." Temperature departures are computed from the appropriate monthly means printed in bold face type in the same source book.

In our early work we found that the seven periodicities discovered by the writer in solar variation[3] and a few others have their counterparts in temperature departures. Figure 1 shows, for instance, a study of the departures from normal monthly temperatures for Clanton, Alabama, for the years 1918-1930. It is apparent that the residual remaining after removing periodic terms is small.

B. THE SUN-SPOT INFLUENCE

When we expanded our research to embrace records extending from 1875 to 1925, we were embarrassed like other investigators by changes of phase and amplitude in the periodic terms. It occurred to me that since the periodicities employed were nearly related to the sun-spot period of 11 years, it might well be that they would be altered with the number of sun spots prevailing. This proved to be true. Figure 2 shows, for instance, the 11-month periodicity in the departures from normal temperature at Bismarck, North Dakota. The results are as computed from four groups of data between 1875 and 1925, segregated with reference to the sun-spot numbers corresponding. It will be seen that the phases remain unchanged throughout this 50-year interval when obtained for homogeneous groups chosen from sun-spot considerations, but alter steadily from group to group as the sun-spot activity increases.

Thus it is apparent that the sun-spot activity produces an important influence on weather not heretofore recognized. This unperceived influence has no doubt disappointed many meteorologists in their studies of periodicities.

C. THE 23-YEAR CYCLE

In the year 1908 Dr. George E. Hale at Mount Wilson Observatory discovered magnetism in sun spots. He soon found that magnetic polarities are opposite in adjacent spots. Following up the investigation it was disclosed that the order of the two polarities is opposite in

[3] Abbot, C. G., Weather dominated by solar changes. Smithsonian Misc. Coll., vol. 85, no. 1, 1931; also, Forecasts of solar variation, ibid., vol. 89, no. 5, 1933.

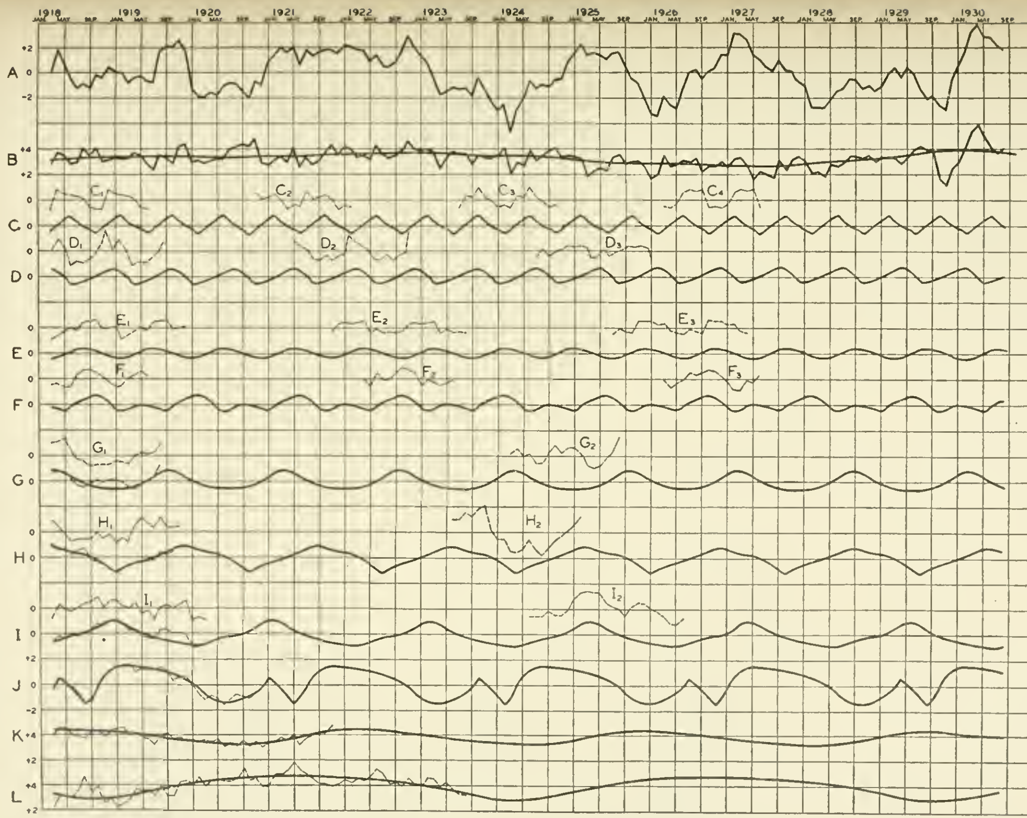

FIG. 1.—Analysis of the smoothed departures from normal monthly mean temperatures at Clanton, Alabama, 1918-1930. Curve A, original data; curve B, residual remaining after removing summation of periodicities shown below. Curve B discovers the 11-year sun-spot temperature effect.

Curves...........................	C	D	E	F	G	H	I	J	K	L
Periods in months................	8	9-1/2	11	16	18	21	25	33	45	68

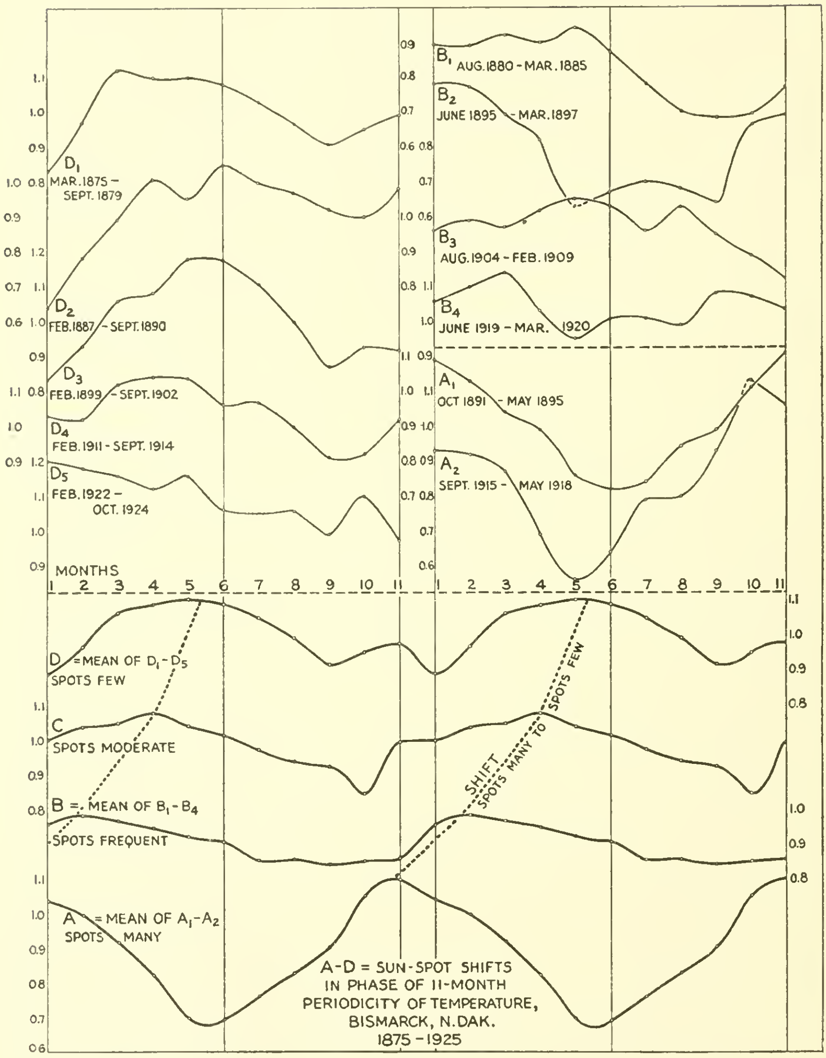

FIG. 2.—Phase-change in periodicity of temperature departures from normal associated with increasing sun-spot activity.

the north and south solar hemispheres and that the order continues unchanged through each 11-year sun-spot period, but reverses at the beginning of the next period. Thus it requires two 11-year periods to bring the sun through a full cycle of magnetic changes.

The writer first noticed about July 1933 that the periodicities found in solar radiation and in the weather were closely related to Hale's magnetic cycle. But numerous studies led the writer to assign to it the length of exactly 23 years, or 276 months. Dividing this period into submultiples, we find as follows:

Name	a	b	c	d	e	f	g	h	i	j	k
Divisor	3	4	6	8	11	13	15	18	25	34	39
Period, months	92	69	46	34-1/2	25-1/11	21-3/13	18-2/5	15-1/3	11-1/25	8-2/17	7-1/13

Of these periodicities, b, c, e, f, i, j, and k are (within the error of determination) the same that I found in the variation of solar radiation, and the others have been found in terrestrial temperature departures.

Inasmuch, therefore, as Hale's magnetic cycle is the least common multiple of so many periodicities in solar and weather variation, it seemed probable that the weather features would be found to repeat themselves at intervals of 23 years. As an illustration, figure 3 shows the smoothed percentages of normal monthly precipitation found at Nagpur in South Central India from 1856 to 1930. The values are arranged in 23-year cycles, so chosen that the year 1875 begins a cycle so as to fit with most of the lists in "World Weather Records." Lines have been drawn to guide the reader's eye to what seem to me to be homologous features in the four cycles illustrated. I would like to call special attention to the regions 1865-1870, 1888-1893, 1912-1917. In 1865, 1868, and 1870 we find three pillarlike features of high percentage precipitation bounding two features of subnormal precipitation. Thus there stand out two intervals of three and two years, respectively, as if guarded by these sentinel features, but embracing nearly a score of subordinate features. The reader's attention is now invited to similar features, 1888-1893, and 1912-1917, in which nearly all the details seem to be recognizable.

The separation between the first and second of these occurrences is almost exactly 23 years, but there is a delay of nearly a year in the appearance of the third. A similar delay marks, however, all of the features from 1899 to 1918, after which the cycle returns approximately to its earlier phase-status. Compare, for illustration, the year 1929 with 1860.

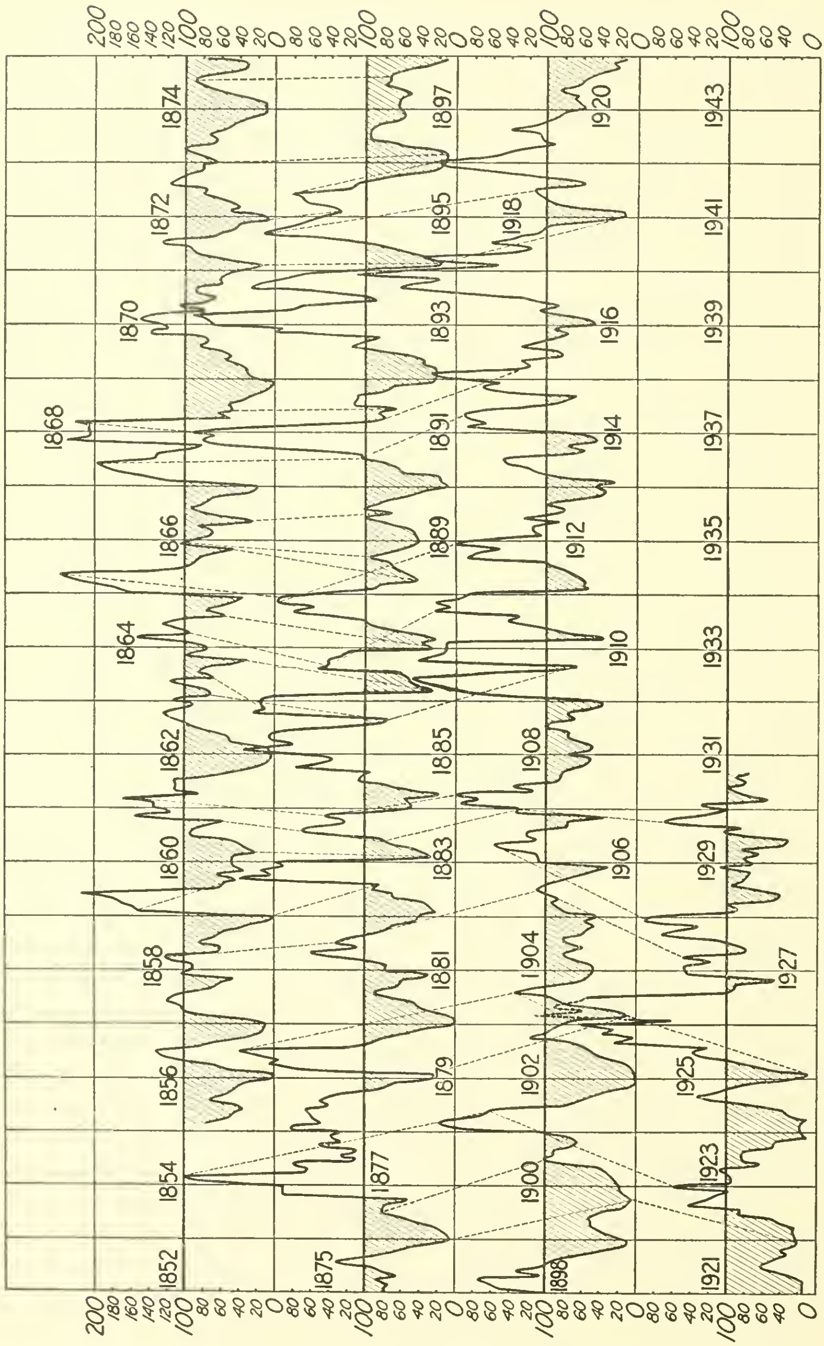

FIG. 3.—Twenty-three-year complex periodicity in the precipitation of Nagpur, India, 1856-1930.

D. THE 23-YEAR CYCLE DURING THE PLEISTOCENE

Reeds has compared the thicknesses of clay varves near Haverstraw, New York, laid down in the glacial period and measured independently by Antevs and himself.[4] From these results I have formed 25 consecutive 23-year groups, and have averaged them in groups of five, and also all together. Figure 4 shows the result of this investigation. Owing to a variety of influences, such as warmths of summers, quantity of rainfall, hardness of the soil, and others which would all affect the thickness of the varves, we should not expect close accord in the individual cycles. Yet the five groups, each covering 115 years, show some similarity, and the general mean for 575 years seems to me fairly conclusive that the 23-year period was as influential during Pleistocene glaciation, some 30,000 years ago, as it is now. Eight principal features occur in the general mean, and I am inclined to believe them to indicate that the sun's radiation varied then as now by several periodicities related to 276 months, and that its variations then as now controlled the weather.

E. FORECASTING WEATHER CONDITIONS

In some cases the 23-year cycle has features of high or low values prevailingly over the course of several years, and repeated nearly similarly during each cycle. Such cases occur, for example, in the Nagpur precipitation cycles from the twenty-first through to the fifth year, during which seven years the precipitation is subnormal. I believe, therefore, that it is probable that subnormal precipitation will be experienced in Central India from 1942 to 1948. Similar indications from studies of records of North Platte indicate subnormal precipitation in central Nebraska from about 1939 to 1948, though with partial relief during two separated years intervening.

When the attempt is made to forecast weather for coming years in more detail than such general statements as these, the embarrassing changes of phase already referred to are encountered. These, though they do not destroy the general sequence of the individual features of the 23-year cycle, produce displacements, sometimes reaching a year, and often several months, in the times of their occurrence. Further research, it may be hoped, will aid in overcoming this difficulty. In order to show the shortcomings of such detailed forecasts if made only with present knowledge, I give in figure 5 predictions of departures from normal monthly temperature and percentages of normal

[4] See Ann. Rep. Smithsonian Inst. 1930, pp. 295-326.

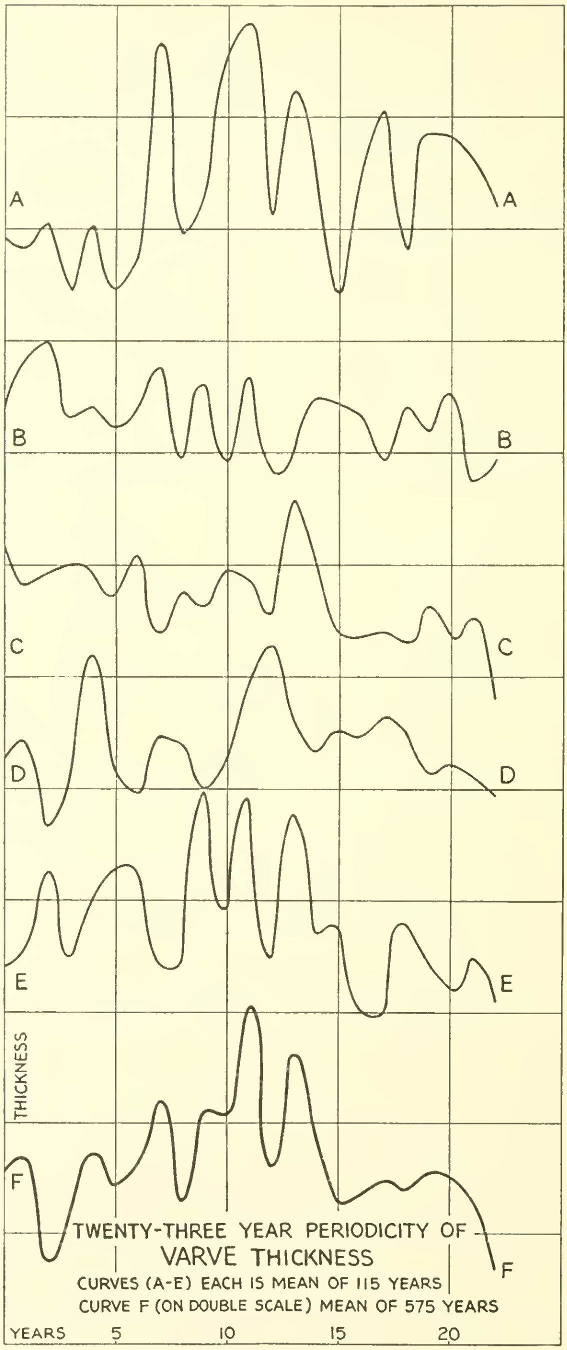

FIG. 4.—Twenty-three-year complex periodicity in the formation of Pleistocene varves.

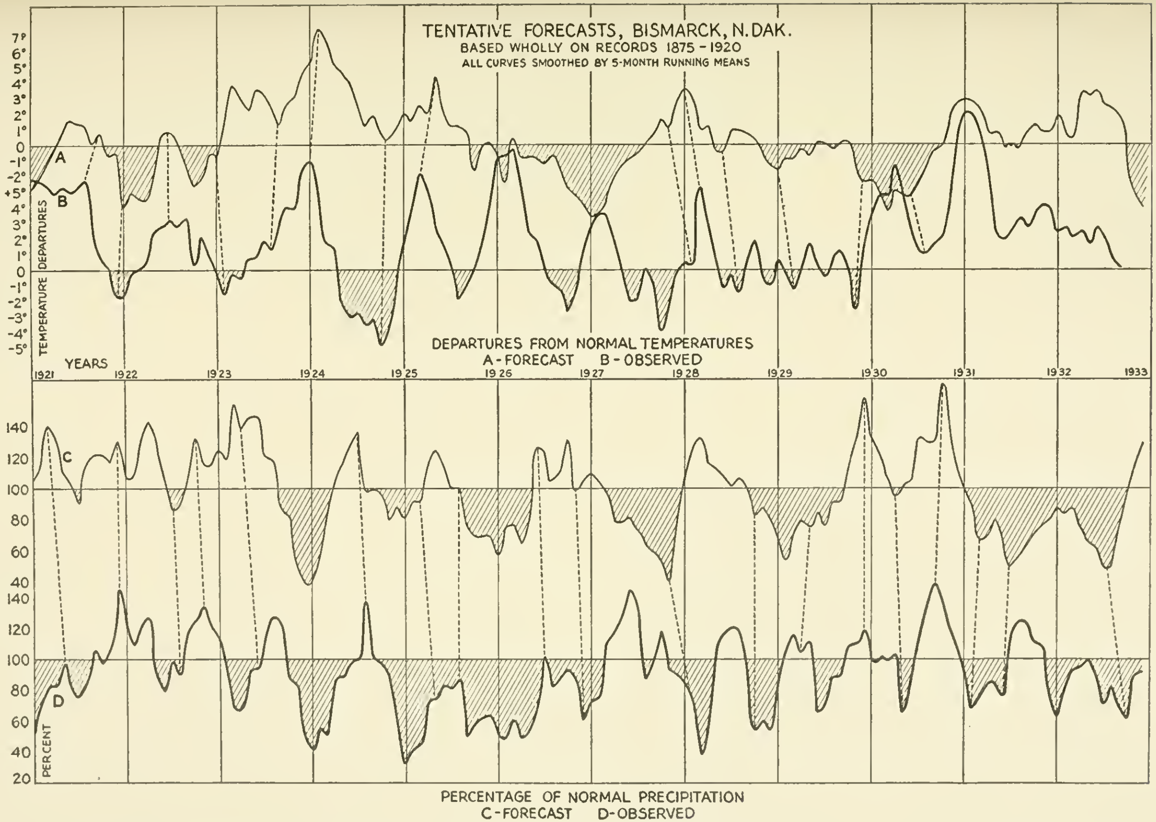

FIG. 5.—Tentative forecasts of temperature departures from normal and percentages of mean precipitation for Bismarck, North Dakota. Twelve-year forecasts, 1921-1932, based exclusively on records of 1875-1920, with verifications.

monthly precipitation for Bismarck, North Dakota. These curves are based solely on records extending from 1875 to 1920, and show the expectation and the event from 1921 to 1932, a forecast and verification covering 12 years. There is considerable similarity (especially from 1921 to 1926 in precipitation) between the forecasts and the events. Yet it would, I feel, be premature to make extensive forecasts of this character. I hope to press forward the investigation.

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AN OLIGOCENE EAGLE FROM WYOMING

BY
ALEXANDER WETMORE
Assistant Secretary, Smithsonian Institution

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AN OLIGOCENE EAGLE FROM WYOMING

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Among the collections obtained by the paleontologic expedition conducted in 1932 by C. W. Gilmore, curator of vertebrate paleontology, United States National Museum, one of the most important specimens is a fossil eagle from Oligocene deposits in Niobrara County, Wyo. This bird was discovered, in beds practically barren of other fossils, by George F. Sternberg, who assisted Mr. Gilmore on the expedition. Great care was used to secure all available fragments, and broken bits have been skillfully fitted together in the laboratory by N. H. Boss, so that the final specimen comprises most of the important elements of the skeleton. The remains form the most complete representation known of an individual bird from the Oligocene deposits of America, and are of great importance in providing information on the early development of the accipitrine group in North America. Description of the specimen follows.

Drawings illustrating the specimen are by Sydney Prentice.

PALAEOPLANCUS STERNBERGI gen. et sp. nov.

Characters.—Somewhat similar to *Aquila* and the larger species of *Buteo,* but metatarsus with projecting wing of second trochlea reduced, differing in this respect from any of the related genera; skull small; premaxilla relatively slender with a pronounced festoon on lower margin; humerus and ulna relatively short and slender; sternum somewhat reduced; furcula with outer, free end greatly narrowed; humerus with ectepicondylar process somewhat reduced; pelvis relatively large; lower limb relatively strong; trochanteric ridge of femur considerably reduced; feet with toes unusually large and strong.

Type.—A partial skeleton, U.S.N.M. no. 12479, collected in the Upper Oreodon beds of the Oligocene on the east side of Plum Creek, Niobrara County, Wyo., on August 9, 1932.

Description.—Skull (fig. 1) with elongated, decurved, pointed tip, premaxilla relatively slender; narial aperture broadly open, somewhat elongated; ascending process of nasal fairly heavy; quadrate heavy; mandible rather slender, with external articular process well developed and internal articular process relatively slight; other characters of skull, particularly the form of the cranium, masked by crushing.

Sternum represented by anterior portion of body only; light in weight and evidently pneumatic; costal margin on left side fairly well preserved and on the right less so; six costal processes indicated, with intervening spaces containing pneumatic openings; manubrium broken away.

Left articular end of furculum (remainder of bone missing) narrow and elongated, differing from the heavier, broader form of living

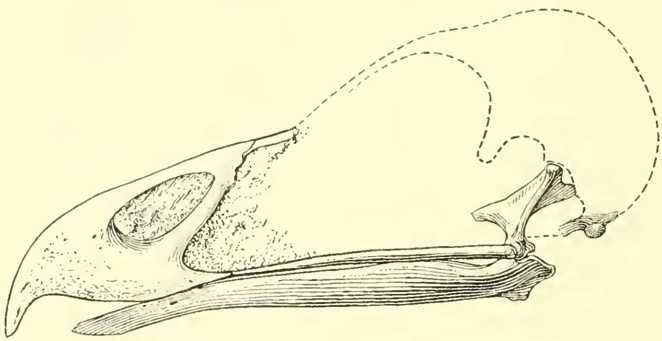


FIG. 1.—Skull of *Palaeoplancus sternbergi*, natural size. The cranial portion, shown by dotted lines, is crushed and distorted in the specimen.

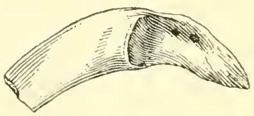
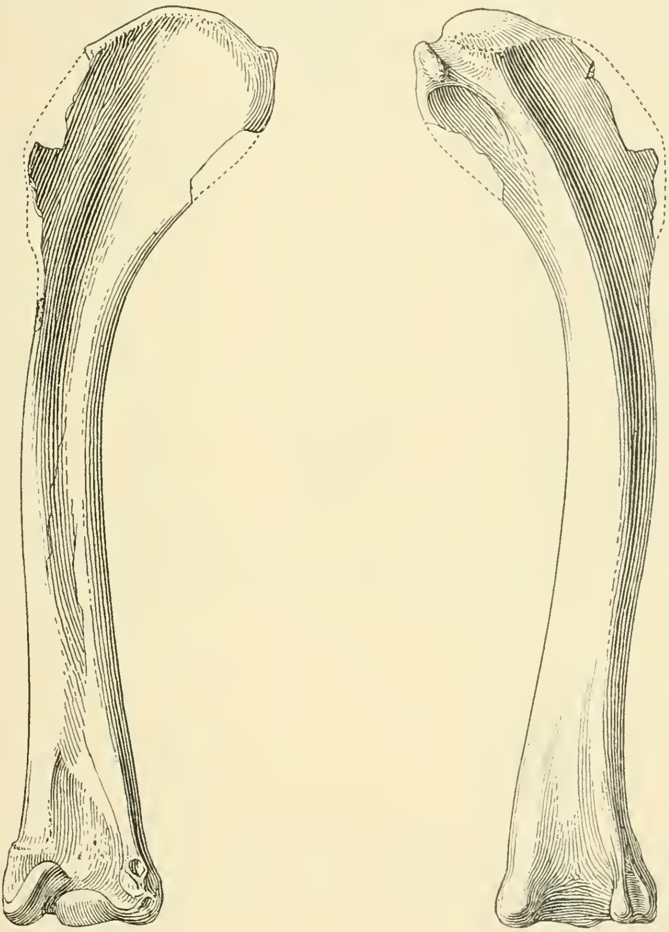


FIG. 2.—Lateral view of left side of furculum of *Palaeoplancus sternbergi*, natural size.

hawks and eagles (fig. 2); coracoidal attachment strongly developed, extending transversely across bone, projecting outward as a sharp ridge; scapular end elongated and pointed; bone evidently pneumatic.

Right humerus (somewhat crushed but nearly complete) strong, with well indicated sigmoid flexure of shaft (figs. 3-4); agreeing in general appearance with humerus in large species of *Buteo*, but with ectepicondylar process somewhat reduced; condyles of distal end moderate in size, somewhat distorted by crushing, so that their form in detail is not clearly evident; deltoid crest strong and well developed; upper end of shaft angularly ridged above line of attachment of latissimus dorsi; head somewhat slender, with characters partly lost by crushing.

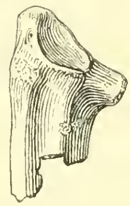
Ulna (figs. 5-6) represented by most of right and proximal and distal ends of left element, strong, of usual buteonine form in so far as the detailed structure has been preserved; more or less crushed and distorted.



3 4

FIGS. 3-4.—Two views of right humerus of *Palaeoplancus sternbergi*, natural size. The specimen is flattened by pressure so that the distal end is somewhat distorted.

Radius (fig. 7), represented by right and left elements with distal ends missing, also relatively strong, of buteonine type; bicipital tubercle elevated and placed a relatively short distance below end of bone.



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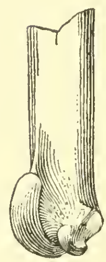

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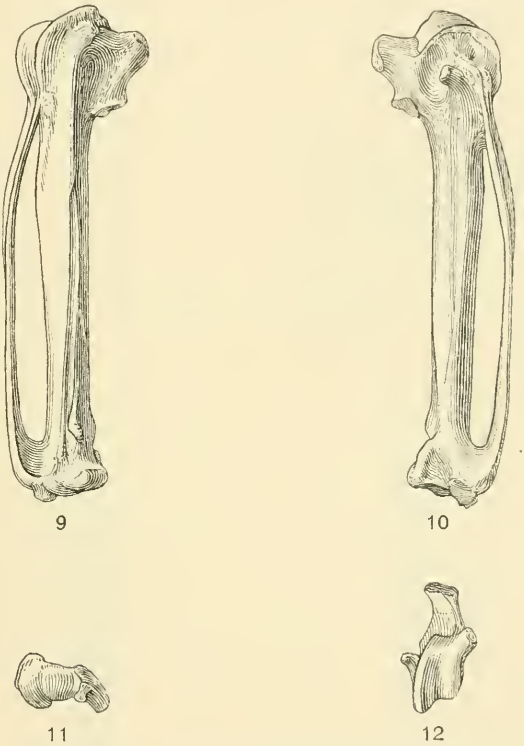
Figs. 5-6.—Proximal and distal ends of left ulna of *Palaeoplancus sternbergi*, natural size.

Fig. 7.—Proximal end of left radius of *Palaeoplancus sternbergi*, natural size.

Fig. 8.—Cuneiform from left wing of *Palaeoplancus sternbergi*, natural size.

Cuneiform bone (fig. 8) present, showing no especial peculiarities.

Metacarpals from both right and left sides (figs. 9-12) preserved (the former nearly complete, the latter with part of anterior end missing); relatively strong and robust; shaft of the second metacarpal particularly heavy; first metacarpal with extensor attachment projecting strongly, the tip inclining inward; attachment for pollex broad,



FIGS. 9-12.—Four views of left metacarpal of *Palaeoplancus sternbergi,* natural size. The smaller figures represent the proximal and distal ends.

the articular surface plane, enlarged by the expanded margins; carpal trochlea strongly angular with the anterior carpal fossa strongly marked; pisiform process projecting as a strong tubercle with a deep internal ligamental fossa about its base; external ligamental attachment also strongly marked; third metacarpal straight and strong, somewhat flattened from above downward toward distal end; a sharply outlined sulcus tendini musculi on outer face extending about two thirds the length of the bone, entirely on the lateral face; muscular

Fig. 13.—Second phalanx of the first digit from the left wing of *Palaeoplancus sternbergi*, natural size.

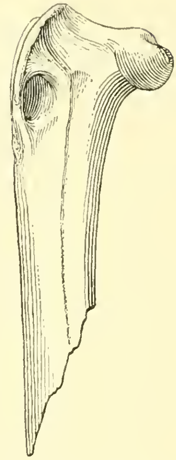
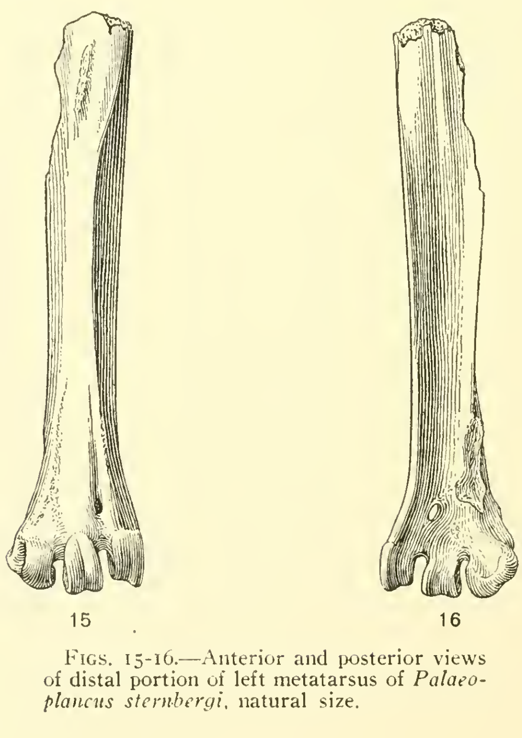


Fig. 14.—Proximal end of right femur of *Palaeoplancus sternbergi*, natural size.



15 16

Figs. 15-16.—Anterior and posterior views of distal portion of left metatarsus of *Palaeoplancus sternbergi*, natural size.

tuberosity at distal end of third metacarpal strongly raised; fourth metacarpal a thin plate, broad proximally and greatly narrowed distally; facet for third digit projecting distally beyond level of second; fornix metacarpi broad and strong.

Second phalanx of first digit (fig. 13) with a broad, strong upper margin, from which a bladelike process projects downward; metacarpal facet broad; digital facet roughly triangular in outline.

Pelvis with anterior portion of synsacrum missing, somewhat fragmentary in other portions; strong and robust, similar in detail, as far as preserved, to buteonine species.

Femur (fig. 14) represented by proximal half of right side (nearly entire) and much of left (badly crushed, so that most of characters are lost); relatively strong and heavy, differing from the buteonine type in relative shortness of the trochanteric ridge, which is considerably restricted; head of usual form, with large impression for attachment of the round ligament; neck relatively heavy; trochanter broad and strong; a single, large pneumatic fossa, oval in form; anterior muscular line strongly marked; shaft strong, elliptical in cross-section.

Metatarsus (figs. 15-16) represented by three fourths of the bone from the left side with the head missing, strong and well developed; outer trochlea relatively heavy (posterior plate missing and rest somewhat cracked and broken); middle trochlea strong with deep excavations on either side and a well-marked groove around articular surface; inner trochlea well developed, with inner face considerably excavated, and outer produced in a thin, bladelike process, the outer point not projecting as far as the body of the trochlea, being more restricted than in buteonine hawks; lower end of shaft flattened, with a heavily marked articular facet for the hallux; inferior foramen oval, with a shallow groove leading into it on anterior face; posterior face of shaft with slightly projecting margins, so that there is the appearance of a broad, shallow groove; outer margin flattened and nearly plane, expanded in center and from there sloping gradually toward either extremity; inner slope on anterior face also flattened, but more irregular; tibialis anticus tubercle elevated, strongly developed.

Of the toes there are present one right first metatarsal, the phalanges of both first toes (fig. 17), the basal phalanx of the right third toe, a third phalanx from a third toe, and part of an ungual phalanx. Hallux remarkably long, being decidedly longer than in *Buteo melanoleucus* (formerly *Geranoaëtus*), in which the metatarsus is larger than in *Palaeoplancus*. The foot, from the few elements present, appears rather slender.

Of the vertebral column the first and a part of the second cervical, parts of three dorsals, the first four caudals, and most of the pygostyle are preserved. Atlas and axis (fig. 18) in size and general form similar to those of the female red-tailed hawk (*Buteo jamaicensis*) (thus matching the relatively small head); dorsals with most of the processes broken away and offering little in the way of characters; pygostyle (fig. 19) and other caudal vertebrae relatively large, being as large as those of *Buteo melanoleucus;* form of pygostyle more like that of *Aquila chrysaëtos;* muscular attachments on all caudals slightly less developed than in the modern species with which comparison is made.

FIG. 17.—Basal phalanx of left hallux of *Palaeoplancus sternbergi,* natural size.

FIG. 18.—Anterior view of joined atlas and axis of *Palaeoplancus sternbergi,* natural size. The bones are somewhat distorted by crushing.

FIG. 19.—Distal view of pygostyle of *Palaeoplancus sternbergi,* natural size.

Measurements (in millimeters).—Skull: Length of premaxilla 29.8; length of mandible (approximate) 67.0.

Atlas: Width 9.0; depth 8.3.

Humerus: Length (approximate) 124.3; transverse breadth across trochlea (approximate) 21.8.

Metacarpus: Length 68.9; greatest height at proximal end 17.5; transverse breadth of shaft at center 5.5; vertical diameter at same point 6.2.

Second digit: Length 27.9; greatest breadth at center 5.2; greatest depth 10.4.

Femur: Transverse diameter through head 20.1; diameter of head 8.3; transverse diameter of shaft 9.6.

Metatarsus: Transverse diameter through trochlea (approximate) 18.0; transverse breadth of outer trochlea 3.0; of middle trochlea 5.3; of inner trochlea 7.0; least transverse breadth of shaft 9.0.

Phalanges: Length of phalanx of first toe 32.3; transverse breadth at base 11.3, at center 6.2; length of basal phalanx of third toe 23.7; length of third phalanx of third toe 19.8.

Remarks.—The general impression obtained from a survey of the skeleton of *Palaeoplancus* is that of a bird with relatively small head like that of a golden eagle, moderately developed wings, strong legs, and large feet with unusually long and powerful toes. The relatively weak development of the tail indicates less rapid flight, or possibly less addiction to soaring, than is seen in our living buteonine hawks and our eagles, but at the same time the strong feet suggest a predatory habit, and the grappling of active prey.

After some consideration of the peculiarities of the metatarsus, furcula, and humerus, and the other features mentioned in the diagnosis, it is seen that *Palaeoplancus* does not fall into any of the recognized subfamilies of the Accipitridae. It is like the buteonine group in general but differs in the points already indicated. The form of the pygostyle and of the furcula are somewhat like those of *Haematornis* (formerly called *Spilornis*[1]) in the Circaëtinae, but no close alignment with this group is indicated. It seems necessary to propose that the form here described be recognized as a distinct subfamily to be called **Palaeoplancinae**, which should be placed between the Buteoninae and the Circaëtinae.

The species is named in honor of George F. Sternberg, skilled collector of vertebrate fossils, through whose efforts many valuable specimens have come to the National Museum.

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[1] Swann, H. K., A monograph of the birds of prey, pt. 11, April 1, 1933, p. 147.

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PLIOCENE BIRD REMAINS FROM IDAHO

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During the field seasons 1929 to 1931 the Smithsonian Institution has carried on paleontologic explorations near Hagerman, Idaho, which have yielded a most remarkable collection of fossil horse bones, a few other mammalian remains, and scattered bones of other vertebrates. The beds in which this material occurred were brought to attention in 1928, when Dr. Harold T. Stearns, of the United States Geological Survey, during geologic studies in this area, was told of fossil deposits by Mr. Elmer Cook, a local resident. Dr. Stearns obtained from Mr. Cook a small collection of fossilized bones, and this collection, forwarded through the Geological Survey to the United States National Museum for examination, appeared so promising that the following June the late Dr. J. W. Gidley, assistant curator of mammalian fossils in the National Museum, went to Hagerman and made preliminary collections. These indicated that the deposits constituted one of the important discoveries in vertebrate paleontology in recent years, so that in May 1930 Dr. Gidley again visited the site to continue work for the summer. The following year field-work was pursued under the direction of Norman H. Boss, chief preparator in the division of vertebrate paleontology of the National Museum.[1] The resulting collections from 3 years of effort include one of the most remarkable known series of fossil horse bones, of a species named by Dr. Gidley *Plesippus shoshonensis*.[2]

The fossil-bearing beds are in what is known as the Hagerman Lake beds. Although regarded by earlier authorities as Pleistocene, Stearns, through his detailed studies of this area, has placed these beds in the Upper Pliocene, in which conclusion he is supported by Gidley.[3]

The principal quarry from which the fossil horse material was obtained is located in the face of the slopes lying above Snake River

[1] See Explorations and Field-Work of the Smithsonian Institution in 1931, Smithsonian Publ. 3134, 1932, pp. 41-44, figs. 35-39.

[2] Journ. Mamm., 1930, p. 301.

[3] For an account of Gidley's field-work in this area see Explorations and Field-Work of the Smithsonian Institution in 1929, Smithsonian Publ. 3060, 1930, pp. 31-34; idem, in 1930, Smithsonian Publ. 3111, 1931, pp. 33-40.

about 2 miles in an airline west of Hagerman, the exact locality being NW¼ Sec. 16, T. 76, R. 13 E. The elevation is about 400 feet above the level of Snake River. According to Gidley,

the bone deposit was evidently at the time of its formation a boggy, springy terrain, perhaps a drinking place for wild animals. . . . . This assumption is based on the general character of the deposits as stated, and the fact that it contains the bones of literally hundreds of animals, mostly belonging to an extinct species of horse. For the most part the bones are disarticulated, intermingled, and scattered in a way to suggest that they represent the slow accumulation of many years rather than the sudden overwhelming of a large herd in one grand catastrophe. Springs and swampy conditions are indicated from the fact that there are in the deposits the remains of frogs, fish, swamp turtles, beavers, and other water living animals, and abundant evidence of vegetation.

The bones were found mainly in unconsolidated beds of sand and gravel.

Considering the nature of these deposits and the large numbers of parts of other animals present, remains of birds are few, only two bird bones coming from the main quarry—a fragment of a swan humerus collected by Gidley and a bit from a pelican collected by Boss.

For bird remains, a locality about 3 miles south of the fossil quarry described above is of more importance, as Gidley, assisted by S. P. Welles and Elmer Cook, obtained there in June 1930 a number of fragmentary specimens. These were labeled by Gidley as " from about 200 feet above level of Snake River and estimated to be about 200 feet below horizon of fossil horse (*Plesippus shoshonensis*) quarry ". The deposit is Upper Pliocene. Additional specimens were collected subsequently at this point by Elmer Cook.

It is unfortunate that the majority of these specimens are not more complete, as a highly interesting avifauna is indicated; but with most of the species represented so indefinitely that they cannot be described their generic affinities are uncertain. To assign them names at this time would only give rise to uncertainty in subsequent work, so that they are listed with whatever discussion seems pertinent in the hope that further specimens may come to hand.

Two additional specimens of the large *Cygnus* come from a locality designated as Canyon 9, 5¾ miles south of the main quarry, and at the same level as the fossil horse deposit.

Subsequent to the field-work outlined additional specimens have been obtained from time to time from Mr. Cook, who found them in scattered areas south of the main quarry. Occurring also in Upper Pliocene deposits, these include fragmentary remains of several aquatic species of considerable interest.

The assemblage of birds is wholly of species of aquatic habit, thus bearing out Gidley's belief that the deposits were formed in bogs or swampy areas.

A detailed discussion of the birds identified follows. Drawings illustrating this report have been made by Sydney Prentice.

ANNOTATED LIST

Order COLYMBIFORMES

Family COLYMBIDAE. Grebes

COLYMBUS sp.

The distal end of a left humerus (U.S.N.M. no. 12825) was found by Elmer Cook in October 1930 at a site 6 miles south of the main quarry and about 300 feet above the level of the river. The specimen is identical in form with living *Colymbus nigricollis* and *C. auritus*, these two being identical in conformation and also indistinguishable in size in the part concerned.

Colymbidae

The head of a femur (U.S.N.M. no. 12242) from the deposit 3 miles south of the *Plesippus* quarry and 200 feet above Snake River comes from a grebe, intermediate in size between the horned and the Holboell's grebe, that differs in its details from any of the genera of the family Colymbidae found in North America today. It seems to represent a distinct genus and certainly an unknown species but is considered too fragmentary to name at present.

Order PELECANIFORMES

Family PELECANIDAE. Pelicans

PELECANUS HALIEUS sp. nov.

Characters.—Radius (figs. 1, 2) similar in form to that of modern *Pelecanus erythrorhynchos* Gmelin [4] but much smaller; slightly smaller than modern *Pelecanus occidentalis occidentalis* Linnaeus,[5] with bicipital tubercle located nearer to head.

Type.—U.S.N.M. no. 12233, proximal portion of right radius, collected July 20, 1931, by Norman H. Boss, from Upper Pliocene

[4] *Pelecanus erythrorhynchos* Gmelin, Syst. Nat., vol. 1, pt. 2, 1789, p. 571.

[5] *Pelecanus Onocrotalus β occidentalis* Linnaeus, Syst. Nat., ed. 12, vol. 1, 1766, p. 215.

1

2

Figs. 1-2.—Type of *Pelecanus halieus*, natural size. The smaller drawing depicts the distal end of the bone.

deposits of the Hagerman Lake beds, in the NW¼ Sec. 16, T. 76, R. 13 E., about 2 miles west of Hagerman, Idaho.

Description.—Head quadrilateral in general outline, with angles rounded; humeral facet well depressed; ulnar facet slightly rounded, with head projecting at this point beyond line of shaft; ligamental papilla strong, projecting as a shelf below level of head; bicipital tubercle located only a short space below head, forming a sharp-angled ridge of slight prominence; shaft moderately strong, somewhat inflated below head, flattened slightly from side to side at first, with a marked projection forming a ridge on outer aspect below head; beyond this the shaft becomes somewhat trihedral in outline, with the side facing the ulna more flattened, and then assumes a more rounded form; shaft with a strong sigmoid flexure.

Measurements.—Transverse diameter of head at right angles to ligamental papilla 7.5 mm; transverse diameter of head through and including ligamental papilla 9.5 mm; distance from center of bicipital tubercle to margin of humeral facet 7.0 mm; transverse diameter of shaft near center 6.8 mm.

Remarks.—The radius, while susceptible of identification in dealing with fossil or modern birds, ordinarily is a bone with such slight differential characters that I have usually considered it of doubtful value in determining the identity of species where other material corroborative of the identification was lacking. The specimen used here as a type, though laid aside with scant attention when first brought to me, to my surprise has on study proved to be so characteristic that it serves to establish an extinct form without the slightest doubt or confusion. It is therefore used as the basis for a new name.

In outline this bone is a diminutive replica of the corresponding part in the American white pelican, common today in the general area under discussion. It differs distinctly from the salt-water-inhabiting brown pelicans, in which the bicipital tubercle is located relatively farther below the head. In size *Pelecanus halieus* is slightly smaller than the West Indian race of *P. occidentalis*. Resemblance to the white pelican, except for its smaller dimensions, is remarkably close, so that there is the distinct impression that the bird is closely related to *P. erythrorhynchos*.

Family PHALACROCORACIDAE. Cormorants

PHALACROCORAX IDAHENSIS (Marsh)

Graculus idahensis Marsh, Amer. Journ. Sci., ser. 2, vol. 49, 1870, p. 216.

The distal portion of a left ulna (U.S.N.M. no. 12240) was collected in 1930 about 200 feet above Snake River and the same distance below the fossil horse horizon. The specimen comprises about one third of the bone.

The type specimen of this cormorant is the proximal end of a right metacarpal, including about one half the bone, preserved with other material in the Marsh collection in the Peabody Museum at Yale University. Through the kindness of Dr. Malcolm R. Thorpe, an excellent cast of this type has been available for study, which has made possible proper consideration of its characters and relationships. In general, this type is similar to the metacarpal in modern *Phalacrocorax auritus* but is decidedly larger, being larger, in fact, than any living cormorant. It is about equivalent in size to the extinct Pallas's cormorant, *Phalacrocorax perspicillatus,* from Bering Island, differing from this species in being more slenderly, less heavily, molded.

The fragmentary ulna here under discussion is distinctly larger than that of living cormorants, though not quite as heavy as in *P. perspicillatus.* On this basis of relative proportion it is identified as *P. idahensis.* Its characters in general, aside from dimensions, are those of other cormorants, except that the carpal ridge is somewhat longer. This find represents the second known occurrence of this species.

In the original description Marsh states that his type of *idahensis* "is from a fresh-water Tertiary deposit, probably of Pliocene age, on Castle Creek, Idaho Territory". Dr. O. P. Hay[6] places this locality in the Pleistocene, stating in the last reference given that it is from the Nebraskan stage. On this basis *P. idahensis* was listed as from the Pleistocene in the third and fourth editions of the "Check-list of North American Birds" prepared by committees of the American Ornithologists' Union. Dr. Harold T. Stearns, of the United States Geological Survey, who has done extensive work on the geology of this general area, informs me, however, in recent correspondence that the deposits at Castle Creek are correlative with the Hagerman beds or possibly older. This would place them in the Pliocene, so that *Phalacrocorax idahensis* should be allocated to the Pliocene, instead of to the Pleistocene as generally accepted at present.

PHALACROCORAX AURITUS (Lesson)

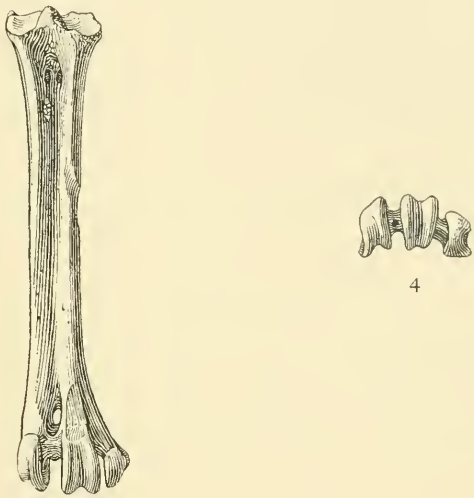
Carbo auritus Lesson, Traité d'Orn., Livr. 8, June 11, 1831, p. 605.

A right metatarsus (U.S.N.M. no. 12239), complete except for slight wear on the margins of its various processes, was obtained in

[6] Bull. U. S. Geol. Surv. 179, 1901, p. 533; and Carnegie Inst. Washington, Publ. 322, 1923, p. 8.

the same locality as the specimen identified as *Phalacrocorax idahensis*, about 3 miles south of the fossil horse quarry, 200 feet above the present level of Snake River, and the same distance below the fossil horse horizon. The specimen, like various others with which it was found, has a slightly porous surface but is well preserved.

The association of this specimen with the fragmentary ulna identified as *Phalacrocorax idahensis* immediately suggested that it might be that species. The relative proportions, however, are such as to indicate with certainty that this metatarsus comes from a much smaller bird,



3 4

FIGS. 3-4.—Metatarsus of *Phalacrocorax auritus* from a Pliocene specimen, natural size.

so small that it must be considered as belonging to an entirely different species.

On careful comparison this metatarsus (figs. 3-4) is found to be identical with that of the existing double-crested cormorant. It is somewhat more slender than many individuals but is equalled in this respect by some specimens of the modern bird. Its contours are so exactly those of the existing species that there can be found no basis whatever for separating it as a distinct form.

While it is commonly recognized that numerous fossils indistinguishable from living species and therefore identified as representing modern birds occur in Pleistocene deposits, it may at first glance seem dubious or even impossible to carry this same procedure back into the Pliocene. The writer has in recent years expressed the belief that our modern avifauna, in so far as its various species is concerned, has had its period of origin and evolution in the Tertiary period, with such changes as have since occurred confined to the minor differences that characterize geographic races or subspecies, these being expressed in color and in slight variations in size. As his work with the avian life of the past proceeds, he has become more and more convinced of these facts. It is therefore only natural to suppose that representation of various modern species will be found in Pliocene deposits as more remains of birds from such horizons are discovered. This may be expected especially among such groups as the cormorants, which appear to be of ancient and long stabilized type.

The modern cormorants of the species *Phalacrocorax auritus* are divided in current usage among four subspecies. Without any attempt to identify the Pliocene metatarsus here discussed as to geographic race, it may be said that it seems closest to *Phalacrocorax auritus albociliatus,* now living in the Pacific coast region from northern Oregon south to Lower California, and on inland lakes from Oregon and Utah south to Arizona and western Nevada.

PHALACROCORAX sp.

Among specimens collected by Elmer Cook are the heads of two coracoids from a cormorant slightly smaller and slenderer than the average for *P. auritus.* One of these (U.S.N.M. no. 12827) was obtained 5½ miles south of the main quarry at an elevation of 400 feet above the river in October 1930. The second specimen (U.S.N.M. no. 12828) was collected 4½ miles south of the *Plesippus* quarry and 350 feet above the stream. These appear to represent a third species of cormorant from this Pliocene locality.

Order ANSERIFORMES

Family ANATIDAE. Ducks, Geese, and Swans

CYGNUS sp.

The material collected in 1930 from the locality 200 feet above Snake River, and the same distance below the fossil horse horizon, includes the head of a metacarpus and the shaft of a metatarsus of a swan having the approximate size of the modern whistling swan, *Cygnus columbianus.* The specimens (U.S.N.M. no. 12238) are worn and broken and cannot be specifically identified. The head of a scapula (U.S.N.M. no. 12830), considerably worn, collected by Cook in November 1930, 5¾ miles south of the main quarry and 400 feet above the river, and another similar fragment (U.S.N.M. no. 12826) obtained by Welles 3 miles south of the main quarry opposite Two-mile Rapids on Snake River are also similar in size to this species.

CYGNUS sp.

Remains of a swan about as large as the modern trumpeter swan, *Cygnus buccinator*, are fairly abundant in the collection here under discussion but are all in such fragmentary condition as to make an attempt at specific identification inadvisable.

A small section of the lower end of the shaft of a right humerus (U.S.N.M. no. 12234) was collected in June 1930 from the main *Plesippus* quarry, being one of the few bird bones obtained from that excavation. This bone differs from the humeri of modern swans examined in having the brachial depression located nearer the external margin.

The locality 200 feet above Snake River, from which the smaller swan was obtained, produced also the proximal ends of two scapulae (U.S.N.M. no. 12243) of a larger species that should be mentioned here. They are about the same in size as the trumpeter.

From another locality designated as Canyon 9, located $5\frac{3}{4}$ miles south of the main *Plesippus* quarry, at the same level as that deposit, there were obtained the proximal ends of two metacarpals more or less fragmentary and worn (U.S.N.M. no. 12236). One of these is slightly larger than the other, the difference probably being individual. A specimen (U.S.N.M. no. 12824) identical with these was collected in a locality indicated as Canyon 8, 5 miles south of the main quarry at an elevation of 200 feet above the river.

CHEN PRESSA sp. nov.

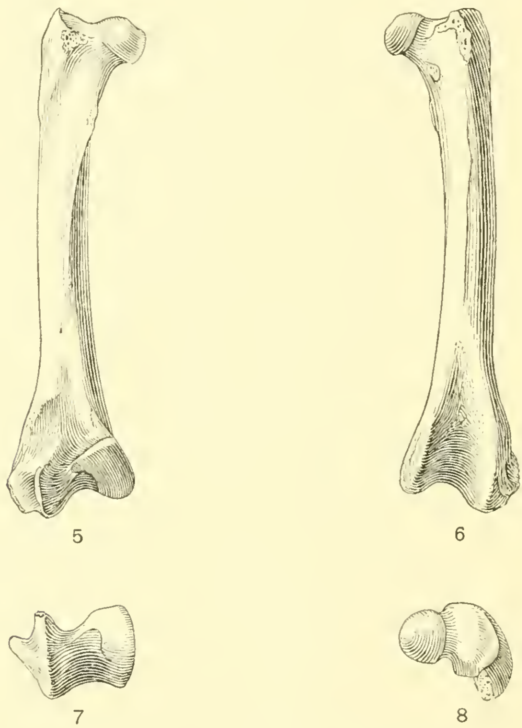
Characters.—Femur (figs. 5-8) similar in form to that of *Chen hyperborea* (Pallas) [7] but smaller; neck shorter, so that the space between the trochanter and the head is decidedly reduced.

Type.—U.S.N.M. no. 12823, left femur, collected in February 1931 by Elmer Cook from Upper Pliocene deposits of the Hagerman Lake beds 1 mile south of *Plesippus* quarry and 350 feet above level of Snake River, near Hagerman, Idaho.

Description.—Head with upper free surface hemispherical (outer surface somewhat broken), indented slightly for the attachment of the round ligament, lower free margin undercut; iliac facet broad and nearly plane; trochanter prominent (partly broken away), approach-

[7] *Anser hyperboreus* Pallas, Spic. Zool., vol. 1, fasc. 6, 1769, p. 25.

ing very near to head and forming an abrupt right angle with the neck, the neck being appreciably shortened; obturator ridge strong and prominent; trochanteric ridge well developed; a strong, sharply ridged linea aspera from below the head down the posterior (lower) surface of the shaft, becoming flattened and disappearing after traversing about three fourths of the length; a nutrient foramen near its



FIGS. 5-8.—Four views of the type of *Chen pressa*, natural size. The smaller drawings represent the proximal and distal ends respectively.

lower end on the posterior face of the shaft; another linea aspera, less elevated, but strongly marked, on anterior surface extending down from the trochanteric ridge for about two thirds the length; shaft strong, straight, somewhat swollen at either end, cylindrical in the center and flattened slightly anteroposteriorly at proximal and distal extremities; fibular condyle well developed (external surface partly broken away) with a flattened fibular groove; external condyle strongly ridged; internal condyle heavily sculptured, flattened on articular surface, rising abruptly from the popliteal area; intercondylar fossa broadly open, leading anteriorly into a broad rotular groove. Bone brownish white, varying to slate or dull white at the extremities and along shaft; strongly fossilized.

Measurements.—Total length 66.9 mm, transverse breadth through head 15.4 mm, transverse breadth of shaft at center 6.7 mm, transverse breadth through condyles 16.5 mm.

Remarks.—The type femur is about the size of the corresponding bone of the emperor goose, *Philacte canagica,* which may be taken as some criterion of the relative size of the new species. In the arrangement of the various tubercles on the shaft and in other particulars it agrees with *Chen* and differs from *Branta,* being closely similar, except as indicated above, to the modern snow geese. It represents an interesting addition to our steadily increasing list of fossil birds.

QUERQUEDULA sp.

In material collected by Elmer Cook there is the distal end of a humerus (U.S.N.M. no. 12829) obtained February 11, 1931, in Canyon 3, 1½ miles south of the main quarry and 350 feet above the river, that represents a teal of this genus, being equal in size to males of *Querquedula discors* and *Q. cyanoptera.*

The upper section of a coracoid (U.S.N.M. no. 12833) secured in 1932, about 3 miles south of the *Plesippus* quarry and about 200 feet lower, agrees also in form and size with this genus, having the head slightly heavier than in *Nettion,* which is about equal in size.

Anatidae

In material associated with the cormorant bones from a locality 3 miles south of the *Plesippus* quarry there is the distal end of a metatarsus and the head of a humerus (U.S.N.M. no. 12241) belonging to this family that cannot be certainly identified. They represent birds about the size of the blue-winged teal; the two may possibly come from one species, though this is not certain. They cannot be allocated to any genus on the basis of present information.

The distal end of a tibio-tarsus (U.S.N.M. no. 12831) obtained by Cook about 3 miles south of the main quarry comes from another species of duck about the size of a shoveller but having the intercondylar sulcus broader than in that species. It is so worn that it cannot be certainly identified.

Order GRUIFORMES

Family GRUIDAE. Cranes

Among miscellaneous fragments from a locality "about 3 miles south of Smithsonian Hill", *i. e.*, from the *Plesippus* quarry, there is a section of the premaxilla of a crane (U.S.N.M. no. 12235) that is as large as the whooping crane, *Grus americana*. This specimen seemingly represents a peculiar type of this family, as the groove on the lower surface is unusually narrow, owing to the approximation of the projecting overhanging walls on either side.

Family RALLIDAE. Rails, Coots, and Gallinules

GALLINULA CHLOROPUS

The distal end of a right tibio-tarsus (U.S.N.M. no. 12822) was found November 8, 1930, by Elmer Cook in Canyon 9, $5\frac{1}{2}$ miles south of the main quarry at a level 400 feet above the river. This specimen agrees in size with males of the modern Florida gallinule, being closely similar to U.S.N.M. no. 318852 male, from Île à Vache, Haiti. While *Fulica* and *Gallinula* are closely similar in this part of the skeleton and in some individuals cannot be separated, this specimen shows the narrowed intercondylar sulcus and the form of the posterior articular surface characteristic of well-marked tibio-tarsi of *Gallinula*. Some modern birds have the intercondylar sulcus broader, but as indicated above this fossil is identical with at least one modern skeleton at hand.

The identification of this bone carries this species back into the Pliocene; it has been recorded previously as fossil from the Pleistocene of the Seminole Field and Itchtucknee River, Florida.

Rallidae

The distal end of a tibio-tarsus (U.S.N.M. no. 12237) from the deposit 3 miles south of the fossil quarry, and 200 feet above Snake River, is distinctly ralline in form, but from the fragment at hand cannot be definitely allocated except to state that it represents either a coot (*Fulica*) or a gallinule (*Gallinula*)—probably the former. It comes from a bird about one half or less the size of the modern American coot.

Another species of this family, represented by a fragment of a metacarpal intermediate in size between the sora (*Porzana carolina*) and the king rail (*Rallus elegans*), was collected by Elmer Cook in 1932 at a point about 3 miles south of the *Plesippus* quarry, and 200 feet lower in elevation (U.S.N.M. no. 12832). The specimen is too fragmentary to be definitely identified.