PROCEEDINGS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY

HELD AT PHILADELPHIA

FOR

PROMOTING USEFUL KNOWLEDGE.

VOL. XXXVI.

JANUARY TO DECEMBER, 1897.

PHILADELPHIA:
THE AMERICAN PHILOSOPHICAL SOCIETY.
1897

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VOL. XXXVI. JANUARY, 1897. No. 154.

Stated Meeting, January 1, 1897.

The President, Mr. FRALEY, in the Chair.

Present, 16 members.

Correspondence was submitted and letters of acknowledgment presented.

Letters of acceptance of membership were received from Prof. W. F. Magie, Princeton, N. J.; Mr. G. Albert Lewis, Philadelphia; Prof. B. W. Frazier, South Bethlehem, Pa.

The death was announced of Gen. John Meredith Read, Paris, France; born Feb. 21, 1837; died, Dec. 27, 1896, æt. 59.

The Judges and Tellers of the annual election reported the following officers elected for the ensuing year.

President.

Frederick Fraley.

Vice-Presidents.

E. Otis Kendall, J. P. Lesley, William Pepper.

Secretaries.

George H. Horn, Persifor Frazer, I. Minis Hays,
Frederick Prime.

Curators.

J. Cheston Morris, Benjamin S. Lyman, Henry Pettit.

Treasurer.

J. Sergeant Price.

Councilors.

George R. Morehouse, William C. Cattell, William P. Tatham, Patterson DuBois.

Mr. Ingham proposed an amendment to the Laws to be considered at the next meeting.

And the Society was adjourned by the President.

Stated Meeting, January 15, 1897.

Vice-President, Dr. PEPPER, in the Chair.

Present, 36 members.

The usual correspondence was submitted with the letters of envoy and of acknowledgment.

Accessions to the Library were reported.

The following Report was read on the part of the Henry M. Phillips Prize Essay Fund Committee :

The Henry M. Phillips Prize Essay Fund Committee respectfully report, that they have found discrepancies existing between the published minutes of the Society of December 7 and 21, 1888, establishing the "Rules and Regulations" in reference to the Henry M. Phillips Prize Essay Fund, and other copies of the same printed in authorized form by the Society, one of these discrepancies presenting a serious embarrassment and hindrance to the effective administration of the Fund. They also find that an incorrect copy of said Rules and Regulations has been improperly included amongst the Laws of the Society in certain pamphlets called "Laws and Regulations of the Society," printed in 1890 and 1894.

They therefore recommend that the Society adopt the following resolutions ;

1. Resolved, That the Rules and Regulations adopted for the management of the Henry M. Phillips Prize Essay Fund as set forth in the circular officially issued by the Committee May 1, 1893, and published in No. 148, *Proceedings* of the Society, July, 1895, pages 174 and 175, are hereby established and adopted, viz. :

First. The Prize Endowment Fund shall be called the "Henry M. Phillips Prize Essay Fund."

Second. The money constituting the Endowment Fund, viz., five thousand dollars, shall be invested by the Society in such securities as may be recognized by the laws of Pennsylvania as proper for the investment of trust funds, and the evidences of such investment shall be made in the name of the Society as Trustee of the Henry M. Phillips Prize Essay Fund.

Third. The income arising from such investment shall be appropriated as follows:

(*a*) To making public advertisement of the prize, and the sum or amount in United States gold coin, and the terms on which it shall be awarded.

(*b*) To the payment of such prize or prizes as may from time to time be awarded by the Society for the best essay of real merit on the Science and Philosophy of Jurisprudence, and to the preparation of the certificate to be granted to the author of any successful essay.

Fourth. Competitors for the prize shall affix to their essays some motto or name (not the proper name of the author, however), and when the essay is forwarded to the Society, it shall be accompanied by a sealed envelope containing within the proper name of the author, and, on the outside thereof, the motto or name adopted for the essay.

Fifth. At a stated meeting of the Society, in pursuance of the advertisement, all essays received up to that time shall be referred to a Committee of Judges, to consist of five persons, who shall be selected by the Society from nomination of ten persons made by the Standing Committee on the Henry M. Phillips Prize Essay Fund.

Sixth. All essays may be written in English, French, German, Dutch, Italian, Spanish or Latin; but, if in any language except English, must be accompanied by an English translation of the same.

Seventh. No treatise or essay shall be entitled to compete for the prize that has been already published or printed, or for which the author has received already any prize, or profit, or honor, of any nature whatsoever.

Eighth. All essays must be *clearly* and *legibly* written, and on one side of the paper only.

Ninth. The literary property of such essays shall be in their authors subject to the right of the Society to publish the crowned essay in its *Transactions* or *Proceedings*.

Tenth. A Standing Committee, to consist of five members appointed by the President, and *ex officio* the President and the Treasurer of the Society, shall continue in office during the pleasure of the Society, and any vacancies that may occur in said Committee shall be filled by new appointment by the President.

Eleventh. The said Committee shall have charge of all matters connected with the management of this endowment and the investment of the same, and shall make such general rules for publishing the terms upon which said prize shall be competed for, and the amount of the said prize, and if it shall deem it expedient, designate the subjects for competing essays. It shall report annually to the Society, on the first Friday in December, all its transactions, with an account of the investment of the Prize Fund, and of the income and expenditures thereof.

2. *Resolved,* That any and all Rules and Regulations relating to the Henry M. Phillips Prize Essay Fund which appear in the printed minutes of the meetings of the American Philosophical Society of December 7 and 21, 1888, or other dates, be, and they are hereby, repealed so far as they are inconsistent with the Rules and Regulations herein contained.

The report was accepted and ordered to be spread upon the minutes, and the resolutions appended were adopted.

It was moved that the Secretary cast a ballot for Dr. G. H. Horn as Librarian for the year 1897. Adopted.

The Secretary reported the ballot cast, and Dr. Horn was declared unanimously elected Librarian for the ensuing year.

Mr. Price moved that Dr. Hays be elected Librarian *pro tem.*, to perform the duties of the office until the return of the Librarian. Unanimously adopted.

A paper by Samuel H. Scudder, entitled "The Species of the Genus Melanoplus," was read by title and referred to the Secretaries for action.

Mr. Mercer then read a paper on "The Fossil Sloth of the Big Bone Cave, Tennessee," which Prof. Cope and Mr. Cushing discussed.

Dr. Frazer presented a "Report of a recent visit to the Black Hills of South Dakota."

Mr. G. T. Bispham offered the following:

Resolved, That a committee consisting of Hon. George F. Edmunds, W. P. Tatham, Esq., W. A. Ingham, Esq., Samuel Dickson, Esq., and Richard L Ashhurst, Esq , be appointed to consider and report whether any, and, if any, what amendments or alterations should be made in the laws of the Society.

Unanimously adopted.

Dr. Frazer moved that Mr. Ingham's proposed amendment to the Laws be referred to that committee. Seconded by Mr. Ingham, and unanimously adopted.

Prof. Cope moved that the President be authorized to appoint the Standing Committees for the current year, and that, with the view of increasing the interest of the membership in the work of the Society, it be respectfully suggested, as far as is possible, not to duplicate the holding of official positions. Unanimously adopted.

The death of the following members was announced :

Dr. Theodore G. Wormley, of Philadelphia, on January 3, 1897, æt. 71 years.

Dr. William Henry Pancoast, of Philadelphia, on January 5, 1897, æt. 61 years.

The Society was then adjourned by the presiding officer.

THE SPECIES OF THE GENUS MELANOPLUS.

BY SAMUEL H. SCUDDER.

(Read January 15, 1897.)

In a memoir to be published by the United States National Museum I have described in detail all the species of Melanoplus known to me, whether new or old. As, however, some delay has occurred in the printing of that paper, I am permitted to give here a table for the determination of all the species and their distribution into series, following it with such portion of the synonymy (given in detail in the memoir referred to) as will enable one to understand the latest determinations made after careful study with abundant material.

The genus, it should be said, is characteristically American, and is widely disseminated. Some confusion has resulted in former times by not recognizing the dimorphism which occurs in this and the allied genera in the length of the organs of flight, a subject discussed at some length in my detailed memoir, where also will be found remarks on their geographical distribution.

Although the prime division in the table separates the macropterous and brachyterous species, the same series and sometimes the same species may appear under both divisions, and the final arrangement of series following the table is independent of this distinction.

I have given the name of furcula to the processes of the last dorsal segment of the male abdomen.

Table of the Species of Melanoplus.

A[1]. Tegmina conspicuously shorter than the abdomen, often no longer than pronotum; furcula almost always developed feebly, generally no longer than the last dorsal segment from which it arises.

b[1]. Cerci of male expanding and bullate from the base outward, abruptly tapering and bent inward at tip; subgenital plate of male abruptly elevated apically (Lakinus series).

c[1]. Interspace between mesosternal lobes of male nearly twice as long as broad;[1] of female, fully half as broad again as long.......................................*marculentus*.

c[2]. Interspace between mesosternal lobes of male distinctly less than twice as long as broad; of female, barely broader or not broader than long.

d[1]. Hind femora heavily fasciate above and on the outer face; hind tibiæ blue throughout................*lakinus*.

d[2]. Hind femora with feeble signs of bifasciation above only, if at all; hind tibiæ pale red, apically infuscated ...*sonoræ*.

b[2]. Cerci of male tapering in the basal half, usually from the very base, sometimes throughout, usually laminate; subgenital plate of male of variable elevation apically.

c[1]. Cerci of male beyond the middle either equal or tapering, sometimes simply styliform throughout, the tip usually more or less pointed, but sometimes broad or truncate;[2] metasternal lobes of male attingent or subattingent.

d[1]. Cerci of male very broad and short, not more than twice as long as the middle breadth, broadly rounded at apex (Flabellifer series).

e[1]. Tegmina about half as long as the abdomen and much longer than the pronotum; cerci of male not longitudinally sulcate apically.

f[1]. Interspace between mesosternal lobes of male twice as broad posteriorly as anteriorly, the inner margins of

[1] This interval is of various shapes in different species of Melanoplus, cuneiform, clepsydral or rectangular, but for the purposes of this table the *middle* breadth is always taken.

[2] The cerci are faintly enlarged apically in *M. meridionalis* and *M. walshii*, which come under this division. See also the note under the alternate category.

the lobes regularly divergent ; of female longer than broad ; cerci of male but little longer than broad...... *discolor.*

f^2. Interspace between mesosternal lobes of male of nearly equal breadth in front and behind, the inner margins of the lobes convex ; of female, transverse ; cerci of male nearly twice as long as broad....*simplex.*

e^2. Tegmina shorter than the pronotum ; cerci of male deeply sulcate longitudinally at apex and incurved.... .. *rileyanus.*

d^2. Cerci of male more elongate, at least twice, generally much more than twice, as long as middle breadth, ordinarily more or less acuminate at apex.

e^1. Cerci of male irregularly tapering, or scarcely tapering at all, compressed, in no sense styliform.

f^1. Subgenital plate of male short and broad, its apical breadth equal to or surpassing the length of its lateral margin.[1]

g^1. Cerci of male long and very slender, in the middle not one-half the width of the frontal costa; last dorsal segment of male with a pair of strongly oblique submedian sulci outside the furcula ;[2] submedian plate not apically elevated (Aridus series).

h^1. Hind margin of pronotum truncato-emarginate ; disk of metazona fully twice as broad as long ; tegmina relatively slender, widely distant.

i^1. Disk of prozona coarsely and uniformly punctate ; cerci of male apically enlarged and inferiorly acuminate at apex.........*humphreysii.*

i^2. Disk of prozona coarsely punctate only along anterior margin ; cerci of male apically equal, rounded at tip........................*nitidus.*

h^2. Hind margin of pronotum obtusangulate but sub-

[1] Care should be taken not to include in the apical breadth any part of the membranous integument connecting it with the preceding ventral segment. For simplicity's sake, the length of the plate is here considered its extent parallel to the lateral margin (or that margin itself) as seen from the side ; its breadth what would be its length along the ventral line were it regarded as one of the abdominal segments.

[2] This has not been seen, but is only inferred in *M. humphreysii.*

truncate; disk of metazona less than twice as broad as long; tegmina relatively broad, approximate, at least in the male........................*aridus.*

g^2. Cerci of male long and broad throughout, subequal, broader than the frontal costa; last dorsal segment of male with no oblique sulci outside the furcula; subgenital plate elevated apically (Indigens series)..............................*indigens.*

g^3. Cerci of male short, or not very long, and broad or moderately slender, in the middle nearly as broad as, if not broader than, the frontal costa; last dorsal segment of male with no oblique sulci outside the furcula; subgenital plate not elevated apically (Mancus series).

h^1. Prozona, at least in male, much longer than broad, the disk of the whole pronotum more than twice as long as the middle breadth, the median carina percurrent, equal; interval between mesosternal lobes of male twice as long as broad ...... *scudderi.*

h^2. Prozona, even in male, transverse, subquadrate or slightly longitudinal, the disk of the whole pronotum less than twice as long as middle breadth, the median carina often subobsolete between the sulci; interspace between the mesosternal lobes of male not more than half as long again as broad.

i^1. Cerci of male rather stout, subequal.

j^1. Abdomen of male strongly recurved; forks of furcula divergent, distinctly longer than the last dorsal segment; subgenital plate with no apical tubercle....................*gillettei.*

j^2. Abdomen of male scarcely recurved; forks of furcula parallel, minute, hardly as long as the last dorsal segment; subgenital plate with a slight apical tubercle...........*artemisiæ.*

i^2. Cerci of male rather slender, especially on apical half, of unequal width.

j^1. Tegmina shorter than the pronotum, broadly rounded or subangulate at apex; cerci of male long and rather slender, nearly straight as seen laterally..................*mancus.*

*j*². Tegmina as long as or longer than the pronotum, apically acuminate ; cerci of male short and not very slender, rather strongly bent-arcuate, as seen laterally. . . . . *cancri*.

*f*². Subgenital plate of male distinctly narrower than long, often narrowing apically.

*g*¹. Cerci of male tapering but little, generally rather stout, or if slender then tapering almost not at all in apical half, which is never less than half as broad as the base and is blunt-tipped, rarely, as in *M. juvencus*, angulate below.

*h*¹. Interval between mesosternal lobes of male at least half as long again as broad, sometimes fully twice as long; hind tibiæ usually blue or green (Dawsoni series).

*i*¹. Cerci of male apically turned sharply inward at right angles or even less. . . . . *reflexus*.

*i*². Cerci of male straight or gently incurved, sometimes curved more strongly at apex, but not bent abruptly at right angles.

*j*¹. Lateral margins of subgenital plate of male, as seen from above, regularly convergent nearly to the tip ; furcula developed only as slightly swollen lobes. . . . . *meridionalis*.

*j*². Lateral margins of subgenital plate of male, as seen from above, basally subparallel, apically rather broadly rounded ; furcula developed as a pair of projecting spines or fingers.

*k*¹. Tegmina much shorter than the pronotum, widely separated ; interval between mesosternal lobes of female distinctly transverse, as broad as the lobes ; subgenital plate of male with distinct though minute apical tubercle. . . . . *militaris*.

*k*². Tegmina longer than the pronotum, overlapping ; interspace between mesosternal lobes of female quadrate ; subgenital plate of male with minute apical tubercle or none.

*l*¹. Subgenital plate of male not pyramidal, nor elevated apically except by a minute apical tubercle; furcula minute, overlying the supraanal plate by a less distance than the length of the last dorsal segment; cerci of male bent roundly inwards at the apex . . . . *nigrescens.*

l^2. Subgenital plate of male subpyramidal, broadly and roundly elevated at apex; furcula well developed, reaching middle of supraanal plate; cerci very feebly incurved apically. . . . . *dawsoni.*

h^2. Interval between mesosternal lobes of male subquadrate, often gradually widening posteriorly; hind tibiæ usually red (Rusticus series).

i^1. Apical margin of subgenital plate of male more or less elevated or tuberculate, or both, generally well rounded, as seen from above, never transverse.

j^1. Tegmina attingent or overlapping; cerci of male apically rounded; furcula distinctly developed; subgenital plate relatively long, subequal in breadth.

k^1. Interspace between the eyes of male broader than the first antennal joint; cerci of male with arcuate upper margin; subgenital plate apically elevated to a greater or less degree, but never conspicuously.

l^1. Prosternal spine transverse, apically truncate or subtruncate; interspace between mesosternal lobes of female slightly transverse; subgenital plate of male moderately narrow. . . . . *montanus.*

l^2. Prosternal spine subconical, bluntly pointed; interspace between mesosternal lobes of female broadly transverse, sometimes as broad as the lobes.

m^1. Interspace between mesosternal lobes of female narrower than the lobes; cerci of male subequal throughout.

n^1. Prozona but little longer than the metazona; hind tibiæ uniform in color beyond the patellar spot; tegmina transversely convex, so that the dorsal and lateral fields are not distinguished from each other by any angle; costal margin of same regularly arcuate ......*washingtonianus.*

*n*². Prozona much longer than the metazona; hind tibiæ with a broad pallid subbasal annulation; dorsal and lateral fields of tegmina set in distinct planes; costal margin of same angulato-arcuate......*walshii.*

*m*². Interspace between mesosternal lobes of female fully as broad as the lobes; cerci of male scarcely half so broad in the apical half as at base.... *altitudinum.*

*k*². Interspace between the eyes of male no broader than the first antennal joint; anal cerci of male with nearly straight upper margin; subgenital plate not apically elevated though furnished with a backward directed tubercle formed by the angulation of the margin ....*gracilipes.*

*j*². Tegmina lateral, widely separated; cerci of male apically truncate; furcula obsolescent; subgenital plate relatively short, of unequal breadth ....*geniculatus.*

*i*². Apical margin of subgenital plate of male neither elevated nor tuberculate, the margins, as seen from above, apically transverse....*rusticus.*

*g*². Cerci of male tapering distinctly and abruptly, the apical less or almost less, generally very much less, than half as broad as the basal portion, and more or less acuminate (Borckii series).

*h*¹. Subgenital plate of male more or less elevated posteriorly, but with no distinct apical tubercle.

*i*¹. Posterior margin of pronotum not mesially emarginate; tegmina attingent or approximate.

j^1. Interspace between mesosternal lobes of female strongly transverse; lateral carinæ of pronotum rounded so as to be subobsolete; postocular piceous band generally distinct, complete, percurrent............ *.pacificus.*

j^2. Interspace between mesosternal lobes of female subquadrate or feebly transverse; lateral carinæ of pronotum distinct; postocular piceous band generally obsolete or wholly wanting, and even when distinct wholly confined to the prozona................*borckii.*

i^2. Posterior margin of pronotum mesially emarginate; tegmina distinct, lateral.

j^1 Color testaceous with feeble or no postocular dark belt......................*tenuipennis.*

j^2. Color dark fuscous, with distinct and broad postocular band, at least in the male... *missionum.*

h^2. Subgenital plate of male distinctly tuberculate at tip.

i^1. Tegmina more or less widely separated, rarely attingent; interspace between mesosternal lobes of male twice or nearly twice as long again as broad; cerci not finely acuminate at tip....... *fuscipes.*

i^2. Tegmina attingent; interspace between mesosternal lobes of male only slightly longer than broad; cerci tapering, rather regular, subfalcate, finely acuminate at tip.................*scitulus.*

e^2. Cerci of male feebly compressed, substyliform, tapering almost uniformly throughout, apically acuminate (Puer series).

f^1. Tegmina attingent; subgenital plate of male short and broad, its apical breadth surpassing the length of its lateral margin, not elevated apically.......*flabellatus.*

f^2. Tegmina distant; subgenital plate of male distinctly narrower than long, elevated apically............*puer.*

c^2. Cerci of male more or less expanded apically, so as to be broader at some point beyond the middle than at the middle, spatulate or subspatulate;[1] metasternal lobes of male separated by a variable interval.

d[1]. Interspace between mesosternal lobes of male quadrate or subquadrate, rarely half as long again as broad (*M. amplectens*); metasternal lobes of male of variable width.

e[1]. Subgenital plate of male distinctly narrower than long, often narrowing apically.

f[1]. Lateral margins of subgenital plate of male apically meeting more or less acutely, and here furnished with a conical erect tubercle (Inornatus series).

g[1]. Interspace between mesosternal lobes of female slightly longer than broad; anal cerci of male broadly expanded apically; apical tubercle of subgenital plate of male blunt.......................... *inornatus.*

g[2]. Interspace between mesosternal lobes of female distinctly transverse;[2] anal cerci of male very feebly expanded apically; apical tubercle of subgenital plate acute.

h[1]. Hind femora fasciate; apical half of male cerci moderately broad, the narrowest part more than half as broad as the base; lobes of furcula short.... *viridipes.*

h[2]. Hind femora not fasciate; apical half of male cerci very slender, the narrowest part not more than a third as broad as the base; lobes of furcula long.................................. *decorus.*

f[2]. Lateral margins of subgenital plate of male meeting with a rounded curve which, if apically elevated, does not form a conical tubercle (Fasciatus series).

g[1]. Cerci of male strongly incurved and conspicuously enlarged apically.

h[1]. Cerci of male very slender, in the middle not one-third as broad as at base, the apical lobe feebly bifid; furcula developed as slender spines about a fourth the length of the supraanal plate.. *attenuatus.*

h[2]. Cerci of male stout, in the middle more than

[1] The cerci are barely enlarged apically in *M. viridipes*, which comes under this division. See also the note under the alternate category.

[2] The female of *M. decorus* is not known.

half as broad as at base, the apical lobe single; furcula developed as mere denticulations.........
amplectens.

*g*². Cerci of male at most gently if at all incurved, and feebly if at all enlarged apically.

*h*¹. Metasternal lobes of male subattingent; tegmina shorter than the pronotum; anal cerci of male straight as seen laterally, or slightly upcurved apically.

*i*¹. Cerci of male rounded at tip; furcula scarcely protruding beyond the hind margin of the last dorsal segment; apical margin of the subgenital plate slightly elevated above the lateral margins.

*j*¹. Supraanal plate of male suddenly contracted before the tip; anal cerci regularly incurved throughout; subgenital plate very broad at base .... *saltator.*

*j*². Supraanal plate of male regularly triangular; anal cerci slightly twisted as well as incurved; subgenital plate narrow at base....
rotundipennis.

*i*². Cerci of male truncate at tip; lobes of furcula long; apical margin of subgenital plate in no way elevated above the lateral margins ....
obovatipennis.

*h*². Metasternal lobes of male only approximate; tegmina as long as or much longer than the pronotum; anal cerci of male slightly decurved apically, or at least inferiorly angulate at apex.

*i*¹. Tegmina not much longer than the pronotum; cerci of male delicate, tapering considerably in apical half; subgenital plate only slightly elevated posteriorly, no broader there than at base......................... *juvencus.*

*i*². Tegmina more than half as long as the abdomen; cerci of male coarse and stout, tapering but little in basal half; subgenital plate strongly elevated posteriorly and there very broad......
fasciatus.

*e*². Subgenital plate of male short and broad, its apical breadth equal to or surpassing the length of its lateral margin (Alleni series).

*f*¹. Tegmina twice as long as pronotum; cerci of male relatively long and narrow, fully three times as long as broad.................................*alleni.*

*f*². Tegmina of about the length of the pronotum; cerci of male broad and relatively short, not more than twice as long as broad.......................*snowii.*

*d*². Interspace between mesosternal lobes of male nearly or quite twice, sometimes more than twice, as long as broad; metasternal lobes of male attingent or subattingent.

*e*¹. Subgenital plate of male short and broad, its apical breadth equal to or surpassing the length of its lateral margin (Texanus series).

*f*¹. Tegmina widely separated, lateral; interspace between mesosternal lobes of male more than twice as long as broad; furcula consisting of a pair of exceptionally broad and short plates..............*dumicola.*

*f*². Tegmina subattingent, attingent or overlapping; interspace between mesosternal lobes of male less, generally much less, than twice as long as broad; furcula consisting of a pair of approximate pointed denticulations.

*g*¹. Subgenital plate of male ending in a conical tubercle...............................*variabilis.*

*g*². Subgenital plate of male with no pointed tubercle.

*h*¹. Lobes of furcula longer than broad; extremity of subgenital plate of male elevated, but not noticeably recurved; interspace between mesosternal lobes of male hardly more than half as long again as broad.

*i*¹. Apex of male cerci angulate below...*lepidus.*

*i*². Apex of male cerci equally rounded above and below........................ *blatchleyi.*

*h*². Lobes of furcula broader than long; extremity of subgenital plate of male elevated and considerably recurved; interspace between mesosternal lobes of male nearly or quite twice as long as broad..................................*texanus.*

*e*². Subgenital plate of male distinctly narrower than long, often narrowing apically (Plebejus series).

f[1]. Hind margin of pronotum distinctly though obtusely angulate; interspace between mesosternal lobes of female at least half as long again as broad; apical portion of anal cerci of male distinctly and sharply sulcate exteriorly .... *plebejus.*

f[2]. Hind margin of pronotum rarely angulate, sometimes emarginate; interspace between mesosternal lobes of female (where known) subquadrate; apical portion of anal cerci of male exteriorly tumid or plane.

g[1]. Posterior margin of pronotum distinctly emarginate in the middle; tegmina widely separated; cerci of male elongate, surpassing supraanal plate; subgenital plate broader at base than apically, its apical margin regularly rounded and even ... *gracilis.*

g[2]. Posterior margin of pronotum obtusely angulate or rounded truncate, with at most but feeblest sign of any emargination; tegmina attingent or overlapping; cerci of male relatively brief, not surpassing the supraanal plate; subgenital plate not broader at base than apically, its apical margin angulate or tuberculate.

h[1]. Tegmina shorter than pronotum; posterior margin of pronotum rounded truncate, with feeblest signs of mesial emargination; cerci of male curved slightly upward; subgenital plate ending in a blunt rather coarse tubercle .... *inops.*

h[2]. Tegmina longer than pronotum; posterior margin of pronotum distinctly though very obtusely angulate; cerci of male curved feebly downward; subgenital plate ending in a delicate pointed tubercle .... *marginatus.*

A[2]. Tegmina nearly or quite as long as or longer than the abdomen; furcula usually well-developed, generally at least a quarter as long as the supraanal plate, but sometimes obsolete.

b[1]. Cerci of male rapidly expanding from the base towards the middle, as a whole broad and short, flabellate, rarely twice as long as broad, not expanded apically (Flabellifer series).

c[1]. Cerci of male twice as broad in broadest as in narrowest portion.

d[1]. Subgenital plate of male with a distinct though minute independent [1] apical tubercle .... *occidentalis.*

d[2]. Subgenital plate of male with only an obscure trace of an apical tubercle .... *cuneatus.*

c[2]. Cerci of male with no striking inequality in breadth...... *flabellifer.*

b[2]. Cerci of male tapering from the very base towards the middle, rarely equal in basal portion,[2] generally long and slender, and rarely as little as twice as long as broad.

c[1]. Cerci of male beyond the middle either equal or tapering, the tip usually slender or acuminate, never bifurcate.[3]

d[1]. Furcula of male developed as large flattened lobes about half as long as the supraanal plate and exceptionally broad, but apically narrowed by the considerable excision of their inner side ; subgenital plate not elevated apically above the lateral margins (Bowditchi series).

e[1]. Body, tegmina and legs almost wholly green, the hind femora not banded.

f[1]. Sides of disk of prozona with a distinct narrow yellow stripe extending to the upper margin of the eyes ; passage of the disk of pronotum into the lateral lobes more gradual than in the alternate category ; hind tibiæ green ; antennæ apically infuscated. .... *herbaceus.*

f[2]. Disk of pronotum and summit of head uniform in coloration, the forming passing into the lateral lobes with a more distinct angle than in the alternate category ; hind tibiæ blue ; antennæ uniform ... *flavescens.*

e[2]. Body, tegmina and legs brown or testaceous, the hind femora generally banded with dark colors.

f[1]. Forks of the male furcula more or less obliquely or transversely truncate at tip and given an oppositely hooked appearance by the rounded excision of the inner margin ; hind femora generally distinctly banded.

g[1]. Highly variegated, the lateral lobes of pronotum conspicuously marked with an unequal bright flavous

[1] That is, not formed by the culmination of the more or less pyramidal form of the subgenital plate.

[2] In rare instances it expands slightly from the extreme base, but is then greatly expanded apically.

[3] In *M. ater* it enlarges feebly apically.

stripe next the lateral carinæ; male cerci very feebly expanded and externally sulcate apically...... *pictus.*

g^2. Rather uniform in coloring, the lateral lobes with no bright stripe; male cerci in no way expanded apically and tumid rather than sulcate externally.

h^1. Lateral lobes of prozona with a broad and usually distinct piceous band above; tegmina generally distinctly flecked along the middle line.... *bowditchi.*

h^2. Lateral lobes of prozona with a narrow or no distinct band above; tegmina very obscurely flecked, if at all, along the middle line...... *flavidus.*

f^2. Forks of the male furcula rounded symmetrically at tip, the inner margin scarcely more excised than the outer, so that the forks are straight and not oppositely hooked; bands of hind femora scarcely perceptible... *elongatus.*

d^2. Furcula of male variously developed, rarely at all unusually broad and flattened, and then either not apically emarginate on the inner side, or the subgenital plate is considerably elevated apically, or both.

e^1. Subgenital plate of male almost or quite as broad as the marginal length, its apical margin generally notched; cerci broad and nearly equally broad throughout (except sometimes narrowed by the oblique excision of the lower side of the apical half), the basal half scarcely tapering, the whole rarely more than twice and never thrice as long as the middle breadth (except in a few cases and then the apical margin of the subgenital plate is mesially notched), very broadly rounded at apex.

f^1. Apical margin of subgenital plate of male not mesially notched; mesosternum of male variable.

g^1. Apical margin of subgenital plate of male but slightly elevated above the lateral margins and moderately prolonged posteriorly; mesosternum of male in front of lobes flat (Glaucipes series).

h^1. Prozona of male longer than its posterior breadth; lateral carinæ more pronounced on prozona than on metazona; interspace between mesosternal lobes of male twice as long as broad; hind tibiæ blue.......................... *glaucipes.*

*h*². Prozona of male transverse; lateral carinæ more pronounced on metazona than on prozona; interspace between mesosternal lobes of male subquadrate; hind tibiæ red .... *kennicottii.*

*g*². Apical margin of subgenital plate of male conspicuously elevated above the lateral margins and greatly prolonged posteriorly; metasternum of male in front of lobes with a central swelling, forming a blunt tubercle (Utahensis series).

*h*¹. Apical margin of subgenital plate of male entire;[1] lobes of furcula not exceptionally broad; subgenital plate greatly but not excessively prolonged.

*i*¹. Interspace between mesosternal lobes of male more than twice as long as broad; of female a little longer than broad; male cerci more than twice as long as broad, apical margin of subgenital plate, as seen from behind, subtruncate.... *bruneri.*

*i*². Interspace between mesosternal lobes of male much less than twice as long as broad; of female transverse; male cerci less than twice as long as broad; apical margin of subgenital plate, as seen from behind, rounded.. .... *excelsus.*

*h*². Apical margin of subgenital plate of male deeply notched on either side of the middle; lobes of furcula exceptionally broad, subequal throughout; subgenital plate excessively prolonged...... *utahensis.*

*f*². Apical margin of subgenital plate of male mesially notched (Spretus series).

*g*¹. Tegmina extending beyond hind femora, if at all, by not more than the length of the pronotum, generally by much less than that; prozona of male quadrate or very feebly transverse; cerci of male generally almost or quite twice as long as broad.

[1] It is occasionally fissured mesially (perhaps in drying), but not properly notched or bilobed.

h[1]. Cerci of male regularly subfalciform, by both margins being uniformly and distinctly curved rather than bent, and more than twice as long as median breadth .... *alaskanus.*

h[2]. Cerci of male nearly straight as viewed laterally, or slightly bent upward in apical half, rather than curved.

i[1]. Cerci of male distinctly more than twice as long as median breadth, the apical half subequal but narrower than the basal half.

j[1]. Hind tibiæ normally pale glaucous; when red, pale red.

k[1]. Larger, robust; median carina usually as distinct between the sulci as on the anterior portion of the prozona .... *affinis.*

k[2]. Smaller, slender; median carina usually obsolete or subobsolete between the sulci .. *intermedius.*

j[2]. Hind tibiæ bright red .... *bilituratus.*

i[2]. Cerci of male not more than twice as long as median breadth, the apical half not only narrower than the basal half, but itself tapering throughout, obliquely truncate beneath; hind tibiæ usually red.

j[1]. Tegmina brief, not nearly reaching the tips of the hind femora; apical margin of subgenital plate of male greatly elevated..... *defectus.*

j[2]. Tegmina reaching, generally considerably surpassing, the tips of the hind femora; apical margin of subgenital plate of male moderately elevated. .... *atlanis.*

g[2]. Tegmina extending beyond hind femora by the length of the pronotum or nearly as much, often by the length of head and pronotum combined; prozona of male generally strongly transverse; cerci of male not more than half as long again as broad..... *spretus.*

e[2]. Breadth of subgenital plate of male variable but generally narrower than long, its apical margin usually entire;

cerci rarely less than four times as long as middle breadth (when less, at least three times as long, and then the apical margin of the subgenital plate is entire), generally slender, excepting sometimes at extreme apex when there is great disparity in width between the apical and basal halves, the basal half generally tapering considerably, the apical half often much narrower than the basal, rarely showing any excision of the lower margin, the apex narrowly rounded or bluntly pointed.

*f*¹. Subgenital plate of male as broad or nearly as broad at apex as at base, generally elevated apically and often notched (generally narrowly); cerci usually narrowing but little on basal half, the apical half equal and symmetrical, bluntly rounded (rarely truncate or angulate) apically.

*g*¹. Apical margin of subgenital plate of male notched with greater or less distinctness; cerci slender, narrower than the frontal costa, subequal, straight or only gently incurved (Devastator series).

*h*¹. Small species, with tegmina not surpassing the hind femora in either sex; interspace between mesosternal lobes of male distinctly less than twice as broad as long.

*i*¹. Cerci of male narrowed rather than broadened apically.

*j*¹. External surface of male cerci apically dimpled; furcula with the tapering portion relatively broad, distinctly flattened, almost reaching the middle of the supraanal plate.

*k*¹. Prozona of male longitudinal; fingers of furcula parallel; cerci bent inwards apically .... *diminutus*.

*k*². Prozona of male quadrate; fingers of furcula divergent; cerci gently incurved throughout . ... *consanguineus*.

*j*². External surface of male cerci sulcate through apical third or more; furcula with the tapering portion very slender, not flattened, not nearly reaching the middle of the supraanal plate .... *sierranus*.

i^2. Cerci of male feebly enlarged apically rather than narrowed .... *ater*.

h^2. Medium-sized species with tegmina almost always surpassing the hind femora in the male and usually in both sexes; interspace between mesosternal lobes of male fully twice, generally more than twice, as long as broad.

i^1. Tegmina more or less, generally distinctly and profusely, maculate.

j^1. Lateral lobes of prozona with a generally distinct black band, rarely broken and then by no conspicuous pale oblique stripe........ *devastator*.

j^2. Lateral lobes of prozona with a distinct black band, always broken by a conspicuous more or less arcuate oblique pale stripe ...... *virgatus*.

i^2. Tegmina immaculate or with the feeblest possible signs of maculation.

j^1. Whole body including tegmina very light colored, having a bleached appearance with no dark markings, except (and very rarely) dusky clouds on hind femora......*uniformis*.

j^2. Whole body including tegmina moderately dark, the lateral lobes with a darker stripe and the hind femora distinctly though not conspicuously bifasciate ....*angelicus*.

g^2. Apical margin of subgenital plate of male entire; cerci either broad (broader than the frontal costa or fully as broad as it) and subequal, or else very inequal, tapering rapidly at the base and generally arcuate; hind tibiæ usually red.

h^1. Supraanal plate of male regularly triangular with straight margins; subgenital plate with a postmarginal tubercle at apex (Impudicus series).. *impudicus*.

h^2. Supraanal plate of male with the sides more or less irregular or sinuate by lateral compression, or by the depression of the apical half of the plate; subgenital plate with no postmarginal tubercle, though sometimes with the margin itself apically thickened.

i[1]. Interspace between mesosternal lobes of male distinctly longer, generally much longer than broad, and much narrower than the lobes; metasternal lobes attingent or subattingent in the male (Dawsoni series).

j[1]. Subgenital plate of male broad, at least as broad as long; cerci incurved feebly and gently, or not at all; hind tibiæ red. . *dawsoni*.

j[2]. Subgenital plate of male rather narrow, narrower than long, although short; cerci abruptly incurved apically; hind tibiæ yellow.

k[1]. Tegmina only attaining the tip of the hind femora; supraanal plate of male suddenly depressed in apical half; furcula slightly developed, shorter than last dorsal segment. *gladstoni*.

k[2]. Tegmina considerably surpassing the tip of the hind femora; supraanal plate of male not apically depressed; furcula well developed, about one-third as long as the supraanal plate . . . . *palmeri*.

i[2]. Interspace between mesosternal lobes of male quadrate, almost or a little transverse and but little narrower than the lobes; metasternal lobes of male only approximate (Fasciatus series).

j[1]. Cerci of male no slenderer or hardly slenderer on apical than on basal half, far surpassing the supraanal plate; furcula very slight, not so long as last dorsal segment. . . *fasciatus*.

j[2]. Cerci much slenderer on apical than on basal half, shorter than the supraanal plate; furcula long and slender, reaching the middle of the supraanal plate . . . . *borealis*.

f[2]. Subgenital plate of male conspicuously narrower at apex than at base (generally only half as wide), rarely at all elevated at apex above the lateral margins and never notched;[1] cerci always distinctly narrowing on basal

[1] Except in *M. monticola*, where it is very broadly and shallowly notched by the tubercular elevation of the extremities of the apical margin.

half, the upper angle of the apex prolonged and often subacuminate (Femur-rubrum series).

g^1. Distal half of male cerci much less than half as broad as the extreme base; interspace between mesosternal lobes of male nearly or quite twice as long as broad; tegmina usually surpassing the hind femora.

h^1. Pronotum marked above with light carinal streaks on a dark ground; tegmina dark olivaceous green .... *plumbeus.*

h^2. Pronotum uniform in coloring above; tegmina dark fuscous.

i^1. Furcula not reaching or scarcely reaching the middle of the supraanal plate.... *femur-rubrum.*

i^2. Furcula extending considerably beyond the middle of the supraanal plate ...... *propinquus.*

g^2. Distal half of male cerci distinctly more than half as broad as the extreme base; interspace between mesosternal lobes of male scarcely if at all longer than broad; tegmina usually falling far short of the tips of the hind femora.

h^1. Apical margin of subgenital plate not elevated where it joins the lateral margins, so that it is straight as seen from behind............ *extremus.*

h^2. Apical margin of subgenital plate elevated to form a tubercle where it joins the lateral margins, so that it is broadly notched as seen from behind.. *monticola.*

c^2. Cerci of male more or less expanded apically, so as to be broader at some point beyond the middle than at the middle, spatulate or subspatulate or apically bifurcate.

d^1. Cerci of male simply spatulate or subspatulate, at most moderately broad, apically entire and no broader than at base; furcula always developed as distinct denticulations, generally as long or very long ones.

e^1. Furcula of male long and prominent, the projecting portion much longer than the last dorsal segment from which it springs, generally more than a third as long as the supraanal plate.

f^1. Subgenital plate of male only moderately broad at apex, distinctly narrower than long, never in the least notched and rarely, and then but slightly, elevated apically; furcula rarely (and then but little) less, usually more, than half as long as the supraanal plate; hind tibiæ green or blue, rarely (*M. complanatipes*) reddish yellow (Cinereus series).

*g*¹. Furcula of male only moderately broad at base, tapering uniformly, not more than half as long as the supraanal plate; cerci uniformly incurved throughout, not nearly reaching the tip of the supraanal plate; the latter abruptly and strongly contracted shortly before its tip.

*h*¹. Prozona of male quadrate or transverse; apical margin of subgenital plate of male, as seen from above, well rounded.................*bispinosus.*

*h*². Prozona of male a little longer than its basal breadth; apical margin of subgenital plate of male, as seen from above, rounded-angulate..*terminalis.*

*g*². Furcula of male unusually broad at base, usually tapering unequally, the narrowing beginning beyond the base and leaving a portion of the apex equal and very slender, the whole considerably more than half the length of the supraanal plate; cerci bent suddenly inward before the tip and at the tip reassuming, at least in part, the original course, reaching the tip of the supraanal plate; the latter with no abrupt preapical constriction.

*h*¹. The distal twist of the male cerci conspicuous and involving the apical half of the same.

*i*¹. Furcula of male narrowing uniformly or almost uniformly throughout; hind margin of pronotum very obtusangulate; disk of pronotum dotted obscurely if at all with fuscous..*cyanipes.*

*i*². Furcula of male with a considerable part of the apical portion equal and very slender; hind margin of pronotum only a little obtusangulate; disk of pronotum generally distinctly dotted with fuscous.........................*cinereus.*

*h*². The distal twist of the male cerci inconspicuous, involving only the extreme tip.

*i*¹. Tegmina long and very slender, far surpassing the hind femora, without distinct spots; hind femora strongly compressed; hind tibiæ reddish yellow.................*complanatipes.*

i^2. Tegmina of normal width and but little surpassing the hind femora, maculate along the discoidal area; hind femora normal; hind tibiæ glaucous........................*canonicus.*

f^2. Subgenital plate of male very broad apically, nearly or quite as broad as long, apically generally notched though very feebly; furcula rarely, and then but little, more than a third the length of the supraanal plate; hind tibiæ usually red, but sometimes blue or green (Angustipennis series).

g^1. Hind tibiæ red.

h^1. Prozona of male subquadrate; tegmina very slender, subequal, scarcely expanded on the costa; furcula of male with straight subparallel forks.... *comptus.*

h^2. Prozona of male distinctly longitudinal, much longer than its basal breadth; tegmina of ordinary breadth and costal expansion, tapering; furcula of male with arcuate, strongly divergent forks....... *coccineipes.*

g^2. Hind tibiæ glaucous.

h^1. Furcula of male not more than a third as long as the supraanal plate; tegmina lightly maculate or immaculate....................*angustipennis.*

h^2. Furcula of male more than a third as long as the supraanal plate; tegmina usually heavily maculate ....*impiger.*

e^2. Furcula of male slight, the projecting portion not longer or scarcely longer than the last dorsal segment from which it springs.

f^1. Subgenital plate of male broad, throughout broader than the extreme base of the cerci; apical portion of supraanal plate suddenly depressed just beyond the middle; cerci moderately broad, not much narrowed in the middle, more or less suddenly bent inward near tip, exteriorly sulcate at apex (Packardii series).

g^1. Interspace between mesosternal lobes of male nearly or quite twice as long as broad.

h^1. Median carina of pronotum obsolete or almost obsolete on the prozona, distinct but low on the metazona; extremity of male cerci nearly plane or merely depressed within the margin exteriorly; forks of furcula conspicuously divergent.

i^1. Prozona ordinarily with a broad median dark stripe, made more conspicuous by the much brighter colors on either side, or else light brownish testaceous; antennæ of male but little more than three-fourths as long as the hind femora; hind tibiæ blue or red .... *packardii.*

i^2. Prozona with uniform dingy coloring on disk; antennæ of male almost as long as the hind femora; hind tibiæ red........... *fœdus.*

h^2. Median carina of pronotum tolerably distinct on the prozona, at least anteriorly; distinct and moderately high on the metazona; extremity of male cerci deeply sulcate exteriorly or else tumid; forks of furcula parallel or only slightly divergent.

i^1. Larger species; narrowest part of interspace between mesosternal lobes of male narrower than the narrowest part of frontal costa; sides of head and prozona rarely with any black band; interspace between mesosternal lobes of female strongly transverse; hind femora red beneath; hind tibiæ stout.................. *corpulentus.*

i^2. Smaller species; narrowest part of interspace between mesosternal lobes of male equal to the narrowest part of frontal costa; sides of head and prozona with a black band; interspace between mesosternal lobes of female subquadrate; hind femora yellow beneath; hind tibiæ slender. *conspersus.*

g^2. Interspace between mesosternal lobes of male subquadrate .... *compactus.*

f^2. Subgenital plate of male very narrow and narrower apically than the extreme base of the cerci; supraanal plate on the same general plane throughout; cerci slender and much narrowed in the middle, gradually incurved, exteriorly tumid at apex (Plebejus series).

g^1. Subgenital plate of male, as seen from above, apically angulate and tuberculate.......*marginatus*.

g^2. Subgenital plate of male, as seen from above, apically well rounded and simple.......*paroxyoides*.

d^2. Cerci of male apically bifurcate, or with an inferior submedian process or abrupt angulation, or else expanded so as to be distinctly, generally much, broader apically than at the extreme base; furcula wanting or minute, rarely (*M. arizonæ*) a fourth as long as the supraanal plate.

e^1. Size smaller or medium; cerci of male always bifurcate or with an inferior submedian process or angulation; supraanal plate pretty regularly triangular with straight or feebly convex lateral margins; furcula usually distinctly developed, rarely (*M. collinus*) wanting; prosternal spine usually short (Collinus series).

f^1. Lower fork of bifurcation of male cerci much longer than the upper; apical margin of subgenital plate narrowly, abruptly and considerably elevated.

g^1. Small species; interspace between mesosternal lobes of male more than twice as long as broad; of female quadrate; median portion of male cerci cylindrical, not compressed.....................*alpinus*.

g^2. Very small species; interspace between mesosternal lobes of male half as long again as broad; of female transverse; median portion of male cerci compressed.................................*infantilis*.

f^2. Upper fork of bifurcation of male cerci longer than the lower, which is sometimes merely an inferior median or postmedian process; apical margin of subgenital plate elevated, if at all, only broadly, gradually and a little.

g^1. Furcula of male distinctly present; apical margin of subgenital plate distinctly elevated more or less above the lateral margins.

h^1. Furcula of male consisting of slender spines, longer than the last dorsal segment; base of lateral margins of subgenital plate incurved.

i^1. Furcula of male less than a fourth as long as the supraanal plate; apical half of cerci bent upward from the basal course.

j^1. Prozona of male subquadrate; supraanal plate with the apical and basal portions in the same plane; subgenital plate of equal or subequal breadth beyond the middle...... *minor*.

j^2. Prozona of male distinctly longitudinal; subgenital plate with the apical portion elevated above the median; subgenital plate distinctly narrowing beyond the middle . *confusus*

i^2. Furcula of male half as long as the supraanal plate; anal cerci incurved, but otherwise straight. *arizonæ*.

h^2. Furcula of male consisting of brief triangular lobes; base of lateral margins of subgenital plate not incurved.

i^1. Interspace between mesosternal lobes of male twice as long as broad; upper fork of cerci scarcely bent upward above the trend of the basal stem.

j^1. Upper fork of male cerci much shorter than the stem; subgenital plate shorter than broad .... *keeleri*.

j^2. Upper fork of male cerci nearly as long as the stem; subgenital plate of equal length and breadth .... *deletor*.

i^2. Interspace between mesosternal lobes of male scarcely longer than broad; upper fork of cerci bent distinctly upward .... *luridus*.

g^2. Furcula of male absent; apical margin of subgenital plate not elevated above the lateral margins . *collinus*.

e^2. Size medium or large; cerci of male rarely bifurcate or with an inferior process (and then the insect is of large size, which it never is in the alternate category, and the supraanal plate is distinctly shield-shaped, the apical half tapering with much greater rapidity than the basal; or the furcula is absent; or the interspace between the mesosternal lobes of the male is three times as long as broad, which it never is in the alternate category); supraanal plate of variable shape; furcula either absent or very minutely developed; prosternal spine usually long.

f^1. Interspace between mesosternal lobes of male nearly, fully, or much more than twice as long as broad; of female generally longer than broad, rarely quadrate; prosternal spine generally long; tegmina usually clear, or with a marked distinction in color between the dorsal and lateral areas, or with the angle between the two marked by a conspicuous light colored stripe; head less prominent and with less prominent eyes than in the alternate category, the front margin of the pronotum in no way flaring to receive the head.

g^1. Furcula of male entirely absent, or present only as a minute point or bead; hind tibiæ generally yellow, but sometimes red (Robustus series).

h^1. Tegmina fully equal to or surpassing the hind femora; hind tibiæ yellow.

i^1. Cerci of male boot-shaped, the foot as long as the leg, the apical margin deeply emarginate below; markings of the outer face of hind femora so run together as to be more longitudinal than transverse....................... *differentialis.*

i^2. Cerci of male apically expanded only a little more above than below; the apical margin regularly or almost regularly convex; markings of outer face of hind femora transverse.... *robustus.*

h^2. Tegmina somewhat abbreviated, not reaching the extremity of the hind femora; hind tibiæ red or reddish yellow.

i^1. Apical margin of male cerci convex or angulato-convex.

j^1. Tegmina distinctly and considerably spotted with fuscous on the lateral field; cerci of male nearly equal on proximal half, the apical margin convex................. *viola.*

j^2. Tegmina almost uniformly fuscous on lateral field; cerci of male distinctly tapering on proximal half, the apical margin broadly angulate ....*clypeatus.*

i^2. Male cerci apically forked, the apical border being deeply emarginate............ *furcatus.*

g^2. Furcula of male distinctly present, though always very small, angulate, the angle rarely produced; hind tibiæ never yellow, usually red, rarely purplish and yellow at tip (Bivittatus series).

h[1]. Interspace between mesosternal lobes of male distinctly more than twice as long as broad; pronotum with conspicuous light colored lateral stripes on the disk, their outer margin at the position of lateral carinæ.

i[1]. Cerci of male very much more expanded apically above than below, the apical border slightly emarginate below.

j[1]. Hind tibiæ clear red throughout .... *femoratus*.

j[2]. Hind tibiæ purplish basally, yellow (rarely reddish) apically.................. *bivittatus*.

i[2]. Cerci of male apically expanded but little more above than below, the apical border convex, with no emargination below ...... *thomasi*.

h[2]. Interspace between mesosternal lobes of male a little less than twice as long as broad; pronotum unicolorous on disk, any lateral stripes being confined to the position of lateral carinæ.

i[1]. Prozona of male feebly longitudinal; apical margin of subgenital plate considerably elevated and truncate; furcula formed of apically rectangulate lobes .... *yarrowii*.

i[2]. Prozona of male distinctly longitudinal; apical margin of subgenital plate considerably prolonged and subtuberculate; furcula formed of rounded lobes with a slight prolongation....... *olivaceus*.

f[2]. Interspace between mesosternal lobes of male subquadrate; of female transverse; prosternal spine short; tegmina maculate with roundish fuscous spots; eyes of male and head prominent, the front margin of the pronotum flaring to receive the head (Punctulatus series).

g[1]. Of large size; furcula present as a pair of very small denticulations; apical margin of male cerci broadly convex, feebly emarginate on the lower half.. *arboreus*.

g[2]. Of medium size; furcula wanting; apical margin of male cerci angulato-convex with no inferior emargination .... *punctulatus.*

Lakinus series. This contains three species which range from southwestern Nebraska and Colorado to central Mexico. *Marculentus* and *sonoræ* are new species, the former named by Bruner; *lakinus* was described by me in 1879.

Flabellifer series. The six species belonging here are evenly divided between macropterous and brachypterous forms; they are found only west of the Mississippi, and mainly in the Cordilleran region. They are *occidentalis* Thom. (*variolosus* Scudd.), *cuneatus* Brun. MS., *flabellifer* Scudd., *discolor* Scudd., *simplex* sp. nov., and *rileyanus* McNeill MS.

Bowditchi series. Here belong six species found almost altogether in the southwest; only one occurs a short distance east of the Mississippi. The species are *herbaceus* Brun., *flavescens* sp. nov., *pictus* Brun. MS., *bowditchi* Scudd., *flavidus* Scudd. (*cenchri* McNeill), and *elongatus* sp. nov.

Glaucipes series. Two species only belong here: *glaucipes* Scudd., from Texas and northern Mexico, and *kennicottii* Scudd., which ranges from Montana to Alaska.

Utahensis series. The three species belonging here are found mainly in the Cordilleran region from latitude 38° northward; they are *bruneri* sp. nov., *excelsus* sp. nov., and *utahensis* Brun. MS.

Spretus series. There are seven species in this series which range widely, some of them occurring in every part of the United States except the southernmost Atlantic States and most of California, and extending far north as well as to central Mexico. The species are *alaskanus* sp. nov., *affinis* Brun. MS., *intermedius* Brun. MS., *bilituratus* Walk., *defectus* sp. nov., *atlanis* Riley, and *spretus* Uhler.

Devastator series. The species are eight in number and almost exclusively confined to California; it is the characteristic group of the Pacific Coast. They are *diminutus* sp. nov., *consanguineus* sp. nov., *sierranus* sp. nov., *ater* sp. nov., *devastator* Scudd. (*affinis* Coq.) occurring in four forms, *virgatus* McNeill MS., *uniformis* sp. nov., and *angelicus* sp. nov.

Impudicus series. There is but a single species, *impudicus* sp. nov., found in the southern States east of the Mississippi.

Aridus series. Here belong three species found in Arizona, Lower California and the proximate part of Mexico. They are *humphreysii* Thom., *aridus* Scudd., and *nitidus* sp. nov.

Indigens series. Contains a single Idaho species, *indigens* sp. nov.

Mancus series. The five species belonging here are brachypterous, but have a wide range, though most of them are separately local. They are *scudderi* Uhl. (*unicolor* Thom.), *gillettei* sp. nov., *artemisiæ* Brun. MS., *mancus* Smith, and *cancri* sp. nov.

Dawsoni series. A somewhat heterogeneous group with both macropterous and brachypterous species and one dimorphic. They are seven in number and occur almost wholly in the great interior region between the Mississippi and the Rocky mountains, and extend from Alberta to central Mexico. They are *reflexus* sp. nov., *meridionalis* sp. nov., *militaris* sp. nov., *nigrescens* Scudd. (*zimmermanni* Sauss.?), *dawsoni* Scudd., (*tellustris* Scudd., *abditum* Dodge), *gladstoni* Brun. MS., and *palmeri* sp. nov.

Rusticus series. Seven species belong to this group, ranging from Washington, South Dakota and Michigan to southern California, Texas and Mexico, though, excepting in Montana, no two species have yet been found in any one State. They are *montanus* Thom., *washingtonianus* Brun., *walshii* sp. nov., *altitudinum* Scudd. (*marshallii* Scudd., *sanguinipes* Brun. MS.), *gracilipes* McNeill MS., *geniculatus* sp. nov., and *rusticus* Stäl.

Borckii series. The six species grouped here are brachypterous and are mainly confined to the Pacific coast from Washington to California, but one species occurs also in Idaho and Wyoming, and another is known only from San Luis Potosi, Mex. They are as follows: *pacificus* Scudd., *borckii* Stäl, *tenuipennis* McNeill MS., *missionum* sp. nov., *fuscipes* McNeill MS., and *scitulus* sp. nov.

Puer series. Contains only two species from Texas and Florida, *flabellatus* Scudd., and *puer* Scudd.

Inornatus series. Three species belong here, found one in Mexico, another in North Carolina and the third in Illinois and Indiana. They are *inornatus* McNeill MS., *viridipes* Walsh MS. (*viridicrus* Walsh MS., *viridulus* McNeill), and *decorus* sp. nov.

Fasciatus series. This group is not very homogeneous, apart from its containing both brachypterous and macropterous forms. There are eight species and their range is not very concordant; one comes from the extreme north (barren grounds) of Labrador and from Greenland ; two from Florida only ; another from Oregon and

Washington; others occur in Kentucky, North Carolina, Indiana and Texas, while the last ranges across the continent from Newfoundland and New Jersey in the east to Oregon and Washington in the west, and centrally from the Saskatchewan to Colorado. They are: *attenuatus* sp. nov., *amplectens* sp. nov., *saltator* sp. nov., *rotundipennis* Scudd., *obovatipennis* Blatchl. (*longicornis* Sauss.?), *juvencus* sp. nov., *fasciatus* Barnst. (*borealis* Scudd., *rectus* Scudd., *curtus* Scudd.), and *borealis* Fieb. (*septentrionalis* Sauss.).

Alleni series. Two species are known, *alleni* sp. nov., from Iowa and Dakota, and *snowii* sp. nov., from New Mexico.

Femur-rubrum series. A dominant and homogeneous group with five species spread over the continent from Atlantic to Pacific, from central Labrador to central Florida, and from the McKenzie river to Texas and central Mexico. No other series has quite so wide an area of distribution. The species are the following: *plumbeus* Dodge, *femur-rubrum* DeGeer (*erythropus* Gmel., *sanguinolentus* Prov., *devorator* Scudd., *interior* Scudd.), *propinquus* McNeill MS., *extremus* Walk. (*junius* Dodge, *parvus* Prov., *leucostoma* Kirby?), and *monticola* Brun. MS.

Cinereus series. Six species are with one exception found only in the extreme southwestern States, but that exception (the typical species) extends the range to Idaho, western Nebraska and Louisiana. The species are: *bispinosus* sp. nov., *terminalis* sp. nov., *cyanipes* Brun. MS., *cinereus* Scudd., *complanatipes* sp. nov., and *canonicus* sp. nov.

Angustipennis series. The four species occur from Iowa to Utah and from Montana and Manitoba to Texas, though one ranges east to Ontario. They are *comptus* sp. nov., *coccineipes* sp. nov., *angustipennis* Dodge, and *impiger* sp. nov.

Packardii series. The five species are all found west of the Mississippi from British Columbia and Assiniboia to Central Mexico, but occur in California only in the north. They are *packardii* Scudd. (*fasciatus* Scudd.), *fœdus* Scudd., *corpulentus* Brun. MS., *conspersus* sp. nov., and *compactus* Brun. MS.

Texanus series. This group also contains five species, all occurring west of the Mississippi, except one found in the upper Mississippi region. They are *dumicola* Scudd., *variabilis* Brun. MS., *lepidus* sp. nov., *blatchleyi* sp. nov. (*occidentalis* Brun., *viola* Blatchl.), and *texanus* Scudd.

Plebejus series. The five species are distributed among brachypterous and macropterous forms, one being dimorphic. They are widely separated geographically, one ranging from Dakota to Kentucky, while the others are found respectively in Florida, Texas and California. They are *plebejus* Stäl. (*pupæformis* Scudd.), *gracilis* Brun. (*minutipennis* Thom.), *inops* sp. nov., *marginatus* Scudd., and *paroxyoides* sp. nov.

Collinus series. An extensive group, with nine species ranging over the entire United States excepting Alaska and California. They are *alpinus* Brun. MS., *infantilis* Scudd., *minor* Scudd., *confusus* sp. nov., *arizonæ* Scudd., *keeleri* Thom. (*tenebrosus* Scudd.), *deletor* Scudd., *luridus* Dodge, and *collinus* Scudd.

Robustus series. Five large species occurring in the southern half of the United States, but hardly known east of the Alleghenies. They are *differentialis* Uhl., *robustus* Scudd. (*ponderosus* Scudd.), *furcatus* sp. nov., *viola* Thom. (*affiliatus* Uhl. MS.), and *clypeatus* Scudd.

Bivittatus series. Five heavy-bodied species belong here, and together they cover nearly the entire continent and include two of the commonest kinds. They species are: *femoratus* Burm. (*flavovittatus* Harr., *milberti* Serv., *edax* Sauss., *hudsonium* Barnst. MS.), *bivittatus* Say, *thomasi* Brun. MS., *yarrowii* Thom., and *olivaceus* Brun. MS.

Punctulatus series. Two species are known, *arboreus* sp. nov., from the southwest, and *punctulatus* Scudd. (*griseus* Thom., *helluo* Scudd.), from a large part of the country east of the Rocky mountains.

THE FINDING OF THE REMAINS OF THE FOSSIL SLOTH AT BIG BONE CAVE, TENNESSEE, IN 1896.

By Henry C. Mercer.

(Read January 15, 1897.)

The fossil sloth bones found in Big Bone cave, Tennessee, illustrate an investigation at one of the points of contact between paleontology and archæology. They explain an effort made during the last several years by the Department of Archæology and Paleontology of the University of Pennsylvania to settle the question of man's antiquity in North America through a study of the associa-

Fig. 1.—Big Bone cave, at the head of Beech cove, one mile from the left bank of Caney Fork river, and one mile above the mouth of Dry Branch, Van Buren county, Tennessee. On the west slope of the Cumberland table-land, about 1000 feet above the sea. Site of the discovery of the remains of the fossil sloth with attached cartilage.

tion of human with animal remains in caves. Turning away, for a time, from mounds, village sites and buried cities, we have sought the help of the naturalist[1] in a systematic attempt to penetrate the crust of recent earth under foot, to trace man through a mixture of the familiar vestiges of such animals as the deer, the bison, the bear, the beaver, the muskrat and the wolf, still existing in the American forest, and to follow him down into that older world layer next below called the Pleistocene. There we have endeavored to find, if possible, his bones still associated with the remains of the extinct mastodon, the mammoth, the tapir, the giant beaver and the fossil sloth.

Much remains to be done over a wide territory, before the evidence of American caves, for or against man's geological antiquity, can be adequately collected or reasonably summed up. But already in the territory examined in the eastern United States and Central America, some landmarks seem to have been established in the pre-Columbian darkness.

Here are five vertebræ (three dorsal and two lumbar), a rib, a heel bone (calcaneum), an astragalus, four vertebral plates (epiphyses) and one epiphysis of a humerus, pertaining to an animal whose name and history belong to the records of this Society, since the first remains of the creature ever found in North America were presented here by Thomas Jefferson on March 10, 1797. Struck by the size of its formidable claws then shown, Jefferson[2] gave it the name *Megalonyx* (great claw), afterwards adopted by Cuvier. And I have hunted up at the Academy of Natural Sciences, for comparison with my specimens, this other set of bones, the very ones then exhibited by Jefferson, two of the lower limb (radius and ulna), several of the foot (metacarpal), with a couple of claws, and show them again here one hundred years later, where I wish to note the fact that certain of them have been gnawed, like my specimens, by rodents, though all are heavier than the latter, and much older in appearance.

[1] My grateful thanks are herewith returned to Prof. Cope for his identification of the bones of the extinct sloth here referred to; to Mr. S. N. Rhodes for identification of the hair, quills and refuse of smaller animals; while our study of the layers, and the removal of characteristic portions of the earth in small bags would have signified less if Dr. Harrison Allen had not named for us the bats; Mr. Johnson, of the Wagner Institute, an insect; Prof. Heilprin and Mr. Vaux, specimens of clay and a limestone fossil, and Messrs. Thomas Meehan and Stewardson Brown, of the Academy of Natural Sciences, the remains of plants which one by one came to light at home after the specimen bags were opened and their contents studied in the daylight.

[2] See *Transact. of Am. Philos. Soc.*, 1799, Vol. iv, p. 246.

Found by saltpetre diggers, buried a foot or more below the surface in the floor earth of Cromers' cave, Green Briar county, West Virginia, Jefferson's specimens were apparently only a few of a greater series. Col. John Stewart and a Mr. Hopkins, of New York, saved these here shown. Another bone got to Cuvier in France; the rest were lost. But from that time to this fragments of the skeleton of the gigantic extinct sloth, claws, limbs, a skull or two, teeth and vertebræ, came to light, sometimes in caves, sometimes in alluvial deposits, as the century passed. Several bones were found with mastodon remains mired in the soft saline earth around the springs at Big Bone Lick, Ky.; others in a conglomeration of the bones of extinct animals at Natchez, Miss., where a whole skull was rescued, or in the river alluvium at Memphis, Tenn.; others in White cave, Ky., in Adams county, Miss., and in a cave in northern Alabama, from which a well-preserved series was sent by Mr. Tuomey to the Academy of Natural Sciences in Philadelphia. Southern Louisiana must have been well-colonized by the animals whose remains, together with the bones of the fossil horse and mastodon, are thickly bedded at the bottom of the rock-salt diggings at Petit Anse, where the creatures probably came to lick salt,[1] and the Pennsylvanian forest must have abounded with them from twenty to thirty millenniums ago, judging from the great number of crushed skulls, claws and bones, that I have exhumed from the fossil bone-bearing chasm at Pt. Kennedy along with the sabre-toothed tiger, the mastodon and fossil horse.

Jefferson, with no tooth to judge by, supposed the "great claw," as he called it, to be a kind of lion such as Hawkins, Harriot, Willoughby, Claibourne and other old explorers said they had seen or heard of in the American woods, and he quoted the tales of later Virginian hunters, describing a terrible roaring, and the devouring of a horse, by a great carnivore, which (as in the case of the mammoth) he argued might still exist in the western wilderness then unexplored. But Dr. Caspar Wistar[2] and then Cuvier established the analogy of the Cromers' cave bones with the modern sloth of South America. And when no such living carnivore as Jefferson had fancied was ever found, and when the remains discovered later appeared continually in association with extinct animals, the gigantic sloth soon came to be regarded as a characteristic represen-

[1] Joseph F. Joor, M.D., in *American Naturalist* for April, 1895.

[2] *Proc. Am. Philos. Soc.*, Vol. vi, 526, 1799.

tative of a category of tapirs, peccaries, horses and mastodons, which had flourished in the time called Pleistocene, at an epoch one geological degree back of the present, or, according to the last of several geological time estimates, about 30,000 years ago.

Here, then, to return to the particular specimens presented by me, (See Figs. 5–14 and 19) are bones which, from the point of view of anthropology, might be presumed to be very ancient, older than the pyramids of Egypt or the oldest inscribed brick yet found in Babylonia, but which, it must be confessed, appear quite modern. I removed them with my own hands out of the floor earth of Big Bone cave, Van Buren county, Tenn., in last May (1896), while conducting thither an expedition for the Department of American and Prehistoric Archæology of the University of Pennsylvania.[1] Strange to say many have articular cartilage clinging to them. Most have been gnawed by small rodents while still retaining their juices, and for these reasons and because, as we shall see later, they form part of a set of bones doubtless of one and the same animal, obtained from Big Bone cave first in 1835, next in 1884, and now last by me in 1896, they may be classed as pertaining to the most modern-looking if not the most interesting series of remains of the extinct animal ever found in the United States. In this case, since the position and the association of the other specimens alluded to of 1835 and 1884, previously found in the same cave by farmers, were not observed, the bones here shown constitute the only remains of this Big Bone cave animal, whose relation to surrounding facts bearing upon their age has been studied so as to furnish some reasonable conclusion as to how and when the creature got into the cave, and whether or not it was a contemporary of the Indian in the Southern mountains.

In the first place, it should be said, that the bones did not come from a human culture layer, nor from a den of large carnivora. Neither were they found at a site where the cave explorer would have chosen to dig, but rather at a spot where all the conditions of exploration seemed unfavorable. They were rescued from one of the subterranean galleries at the last moment after the whole cave had been rifled for saltpetre.

About one mile from the left bank of Caney Fork river, and

[1] I take pleasure in returning the thanks of the Department and of myself to our Vice-President Dr. William Pepper, who alone defrayed the expenses of this expedition.

one mile above the mouth of a confluent called Dry Branch, in Van Buren county, Tenn., probably 1000 feet above the sea, Big Bone cave opens from the carboniferous limestone upon the head of the "Beech cove," one of the secluded ravines called "coves" that furrow the western slope of the Cumberland table land. Though 600 feet, more or less, and a broken reach of country intervened between the cavern and the high cool region above, its general nearness to the plateau[1] and its elevation promised well for the explorer. Subterranean deposits washed away, or disturbed by water, during the supposed invasion of the lower country by post-glacial floods, might well have escaped destruction in a cave lying as high as this, while the chance of unearthing abundant or ancient mammalian remains was increased, if we were to suppose that animals in great numbers had gathered in the vicinity, or that man, if he existed, had sought refuge upon the plateau during a general inundation.

But the configuration of the cave, at its entrance, disappointed us. By all past experience, the gloomy hole (see Fig. 1) overshadowed with large "tulip trees" was too wet and steep for savage shelter. Water dripped from the low arch forty-two feet wide and only six feet high. The down-washing of rain from the hill above had choked the vault with loose stones, and disturbed any deposit of earth that may ever have existed within sight of the outer world. Just where we had expected to discover evidence of value, at the point where caves are usually richest in significant remains, there was no work for shovel and pickaxe. To our surprise, the point of interest in Big Bone cave lay far beyond the reach of daylight. It

[1] The Cumberland table-land, a flat-topped continuation of the Alleghenies with sandstone top set on limestone base, extending from northeast to southwest across the entire State of Tennessee, comprises, according to Prof. Safford, 5100 square miles, or one-eighth of the State. Rising 1000 feet above the valley of Tennessee and 2000 feet above the sea, its eastern edge forms a generally straight line, while its western escarpment is notched and scalloped by deep "coves" and valleys, where erosion has laid bare the underlying stratum of "mountain" (carboniferous) limestone upon which the plateau is founded. At almost all points on both sides, the surface suddenly breaks off in sandstone bluffs or cliffs from twenty to two hundred feet in height, giving generally a sharp and prominent margin or brow to the plateau. The carboniferous sandstone surface of the high region, overspread with a sandy, coarse and sterile soil, is often flat for miles. Then again it is rolling and diversified with hills and shallow valleys. In the northeastern part there are high ridges containing many beds of coal, which may be regarded as mountains on a table-land. See *Elementary Geology of Tennessee*, by J. M. Safford, Nashville, p. 32.

was only found after turning to the right from the main tunnel and following a small bifurcating passage for 900 feet.

As we groped onward, the cave became dry, and the candles revealed a line of clay stains waist high upon the narrow walls, marking the limit of nitrous earth previously excavated along the entire length of the gallery. Without the superfluous assertions of our guide, James Priest, and the land owner, Mr. G. B. Johnson, we might have inferred that we had entered one of the numerous Appalachian caves, where the floor accumulations, because they contained saltpetre, had been removed by gunpowder makers at times of need in the wars of 1776, 1812 or 1863.[1]

Laden with pickaxe and shovels, baskets, instruments, candles and provisions, now crouching where the roof lowered, now clambering upon a log across an intersecting crevice, eight or nine feet deep, we followed the lead of Priest, until directly on the footway a spot was reached where, in the utter darkness, beyond the range of the continued haltings of men, and probably of large animals, at a point where no human culture layer, under ordinary circumstances, could have been formed, these remarkable bones of the sloth and all other sloth bones, known to have been previously removed from the cave, were found. Elsewhere the evidence of the relation of animals and men to the cavern, whatever its character, had been destroyed.

[1] Judging by the wall stains, from one to three feet of this floor earth had been removed throughout the nine hundred feet of the passage observed, and the large pile of leached earth, just under the entering arch of the cave, the still greater rampart outside and several similar heaps at other points in the neighborhood, where water for leaching was convenient, testified that the numerous "petre diggers" of the war of 1812 (about three hundred in number, said Mr. Johnson) and their successors of the Rebellion, had done a formidable amount of work underground. Many thousands of sacks, full of the pungent earth, had been carried upon their backs by way of devious passages, with many tedious twists and leanings, crawls and squirms from the eternal darkness to daylight. To leach the earth you place it (according to Mr. Johnson) in a wooden funnel-shaped hopper, with a drip orifice at the bottom. After pouring on water, an equal mass of which the dry earth absorbs, the hopper at length begins to drip and continues to drain off a pungent liquid caught in a vat. Having "seeped" for several days, the drops loose their taste, proving that the earth has lost its strength, or is, in other words, leached. Then the treatment of the liquor begins. This is poured through a similar hopper full of wood ashes and drips not, as before, clear, but now darkened with impregnated lye. Boiled down after this to half its volume in kettles, the liquor thickens, and, when allowed to cool, at once hardens throughout suddenly into beautiful cyrstals of pure saltpetre, when it is ready for sale. Such is the process familiar to the memory of many of the wild-looking mountain men, whose subterranean labor, unfortunately for archæology, has destroyed the interesting evidence once furnished by many of the cave floors in eastern Tennessee.

The record of these bones is, therefore, very different from that of animal remains dug out of the rock shelters of Europe, or from that of specimens derived from any layer of caked human rubbish where savages have been wont to take subterranean refuge. Men certainly did not bring them into the cave. Frost had never reached them. Neither would change of temperature have affected them where they appeared to have rested in the dry earth in an unchangeably cool air since the time of their deposition.

Let us describe this place. The roof has expanded over several branching alcoves, partitioned head high by screens of eroded rock. Mysterious crevices in the ceiling rise above us beyond the reach of candle light. There are no stalactites and we feel no trace of dampness. The severe outside heat of the Southern spring has been reduced to a dry and cool subterranean temperature of fifty-five degrees Fahrenheit. Where a flanking screen narrows the gallery to a width of three and four feet, the earth is soft and mealy under foot and covers the whole floor, rising in a cloud of dust when disturbed by a kick. This floor deposit proves on examination to consist of a noxious and volatile mantle of dry, loose excrements, mixed with vegetable remains, covering up and spoiling by its intermixture the nitrous earth resting in lumps beneath it, and thus sufficiently explaining why, as far as saltpetre digging was concerned, that part of the cave had never been disturbed.

To further examine this floor, later to search the surrounding alcoves, and to discover upon several ledges shoulder high a series of ancient water-made holes, large as stove-pipes, down which nuts, leaves, grass and dung had slid, was to explain the existence of the rubbish at that point. The spot had long been and probably was still a den of busy cave rats, who with porcupines, reaching the gallery not by the outer cave entrance but by the air holes described, had brought thither their vegetable food and trophies from the outer world. Though none of the conspicuous nests of dry grasses and moss loosely interwoven, such as I had previously observed lying on the floor of a rat cave on the New river in Virginia, were seen, several wads of moss, found later in the rubbish, seemed to indicate that the *Neotoma magister* had nested there at some time before the visitation of the cavern by saltpetre diggers. Once again let us say that we were directly upon the cave path, where back and forth over the dusty manure all footsteps of all saltpetre hunters, all white men, all Indians, choosing to penetrate deeper into the cave, must needs have passed. Their trampling had draggled the surface, kicking earth into it from other areas, or dropping "petre dirt" upon it from bags. Moreover charred pieces of resinous pine, *Pinus mitis;* twigs of hazel, *Corylus americana*, and fragments of burnt cane, *Arundinaria tecta*, strewed the surface, representing doubtless the remains of the torches of such white nitre hunters as had not had lamps or candles, and, we may reasonably suppose, of the Indians who had preceded them (see Fig. 2). The appearance of this surface film then, which I have called

LAYER I

(2 to 3 inches thick),

thus disturbed for two or three inches, and scattered with lumps of nitrous earth and with these burnt sticks, was sufficient to demonstrate that human beings had visited the cave if no further proof of the fact had existed. Over and above the certainty that white men had long passed and repassed the spot, and that many of the torch ends, and particularly the pieces of pitch pine (which suggested the splitting agency of iron tools), might be referred to them, it seemed reasonable to suppose that some at least of the pieces of charred cane (resembling fragments of *Arundinaria* found by us mingled with aboriginal bones in the sepulchral chasm at Lookout cave) had been cast away at the spot by Indians.

Our party of four, Mr. G. B. Johnson, James Priest, my assistant, Joseph Mussleman, and myself, had stopped, and Priest, our guide, holding down his candle, pointed to a hollow caused by digging in the mass of dry manure, where he about 1884, while filling several bags full of the "fertilizer," as he called it, for his garden, and later Mr. Johnson himself on a similar errand, had found several vertebræ, ribs, the pelvis and the skull with teeth of a large animal (the extinct sloth), which, after remaining for some time at the house of Mr. Johnson, had been sent to Nashville and sold.[1] For this reason, and as well testified by the letters to me of Prof. J. M. Safford, State Geologist of Tennessee, who first advised my exploring the cave, let it be said in parenthesis that without doubt the sloth skull now in the possession of Prof. Safford, at Nashville, and which I have been unfortunately unable to obtain from him for comparative study, is the skull thus found by Priest,

[1] By a Mr. A. J. Denton, as Mr. Johnson informed me.

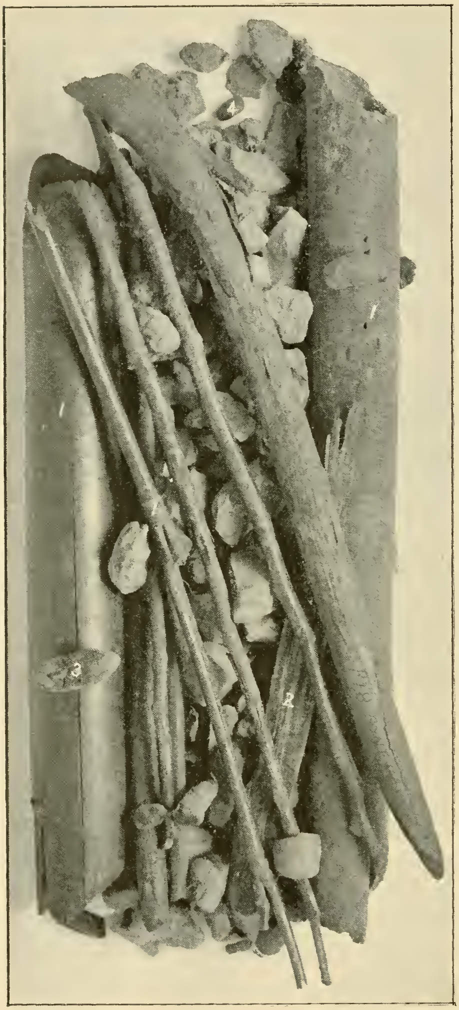


FIG. 2 (x ½).—Specimens of the cave rubbish, fragments of cave clay and coprolites; 3, of porcupine, *Erethizon dorsatus*; 4, of cave rat, *Neotoma magister*, and the cast-away ends of torches resting on the surface of the cave floor (Layer 1), above the spot where the sloth bones were unearthed; 1, *Arundinaria tecta*; 2, charred splinters of pitch pine, *Pinus mitis*, and seven charred twigs of hazel, *Corylus americana*.

and because this skull and the other bones belonging to Prof. Safford, corresponding to those described as found by Priest and Johnson at this place also show cartilage, and further because the evidence indicates that there was only one sloth at this point, with no reason shown why there should have been more than one, and because it appeared that no other spot adapted for the discovery of fossil bones had existed at the entrance of the cave, for these reasons, I believe that the Nashville bones and my set go together as parts of one animal; and further, as first suggested by Prof. Safford and now shown by my examination, let me add that still another and a third set of sloth bones, belonging to the Academy of Natural Sciences of Philadelphia, herewith shown (see Fig. 3 for one of them), found by a farmer in the cave and described by Dr. Harlan in 1835, also showing cartilage

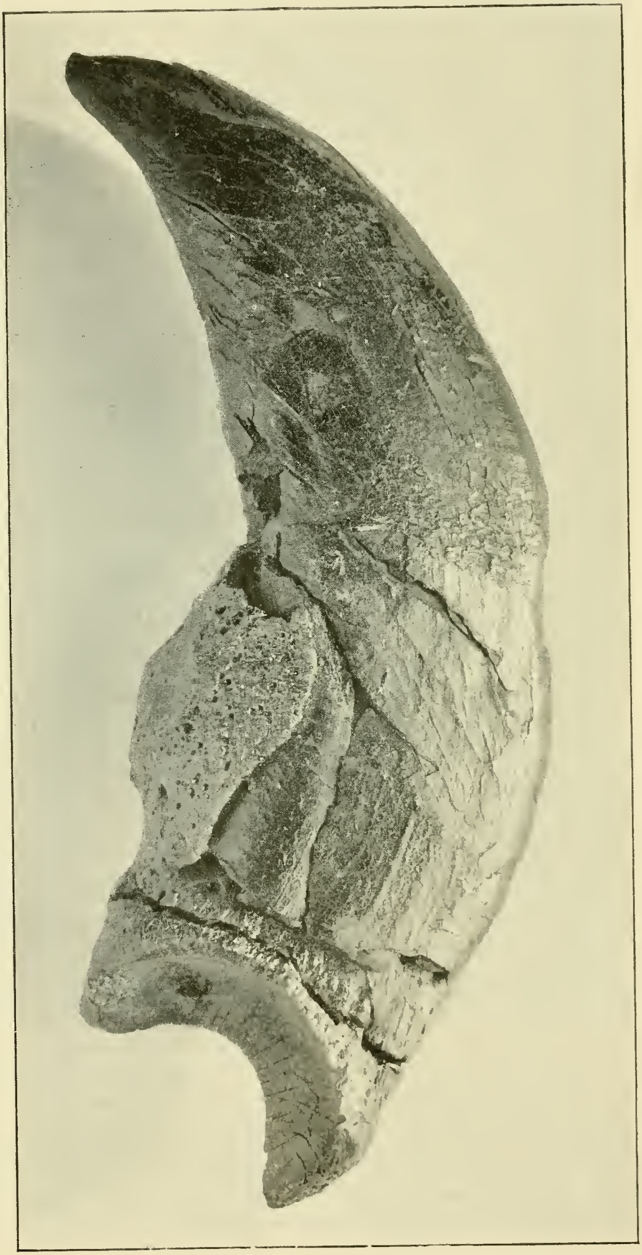


FIG. 3 (actual size).—Claw with cartilage and horny sheath of the sloth Megalonyx, from the J. P. Wetherill collection at the Academy of Natural Sciences of Philadelphia. One of the bones found in Big Bone cave before 1835, and inferentially a part of the same young animal represented by the other illustrations. Red cartilage sticks to the articulation. An *undecomposed* horny sheath covers almost the entire bone. (Photographed by kind permission of Dr. S. G. Dixon.)

equally fresh in appearance and referable to a young animal (because of the loose epiphyses) may well be believed to constitute skeletal portions of the same individual.[1]

These subsequently arrived at conclusions, however, did not concern us when first pausing in the candle light, we placed our tools and baskets upon the ground to listen to the account of Priest. Our hope of finding more bones depended upon the chance that he had not dug up the whole floor and that other remains, resting beyond the limit of his digging, had escaped him and remained to reward our search.

Down through the manure and nitrous earth resting beneath it, from nine in the morning till five in the afternoon, beginning where the consistency of the deposit showed that Priest and other diggers had left off, we worked in the dim candle light, until our hunting had accomplished its object, and until the walls of our trench revealed the facts herewith described, and first that of a sequence in time marked by the layers that had accumulated upon the foothold, and of which two epoch-denoting divisions confronted us. They consisted of (below and older) a water-deposited nitrous clay, resting upon the bottom rock, standing for a time when the cave was wet, and (above and later) the manure previously referred to, testifying to an epoch when the cave was dry, and to the latter division with its subdivisions described as Layers 1, 2 and

[1] Dr. Richard Harlan (see *Medical and Physical Researches*, by Richard Harlan, Philadelphia, 1835, p. 321) describes the set at the Academy of Natural Sciences in 1835. He speaks of and partially figures "two claws of the fore feet, a radius, a humerus, a scapula, one rib and several remnants, an os calcis, a tibia, a portion of the femur, one lumbar and four dorsal vertebræ, the portion of a molar tooth, together with several epiphyses, the bones of a young animal imperfectly formed at the extremities." Distinctly noting the cartilage on several of the specimens, he calls particular attention to the nail on one claw (see Fig. 3). According to him, they were obtained by Mr. Dorfeuille (proprietor of the Cincinnati Musem) from a Mr. Clifford of Kentucky, bought from Dorfeuille by Mr. J. Price Wetherill, and presented by the latter to the Academy of Natural Sciences. Harlan had in another paper referred to these bones as coming from White cave, Kentucky, and after repeating the statement here corrects it at the last moment with a footnote which says, "According to the recent observations of Dr. Troost, these bones were derived from the Big Bone cave, Tennessee." My guides' Priest and Johnson had heard of the discovery of other sloth bones at the cave in the early part of the century, and for the reasons above given I have no doubt that the nitre diggers (of 1812 probably) found them at the site of the other discoveries, and that Clifford obtained them through intermediaries. Interesting details of this first discovery would probably appear in Dr. Troost's communication to Dr. Harlan if it could be found.

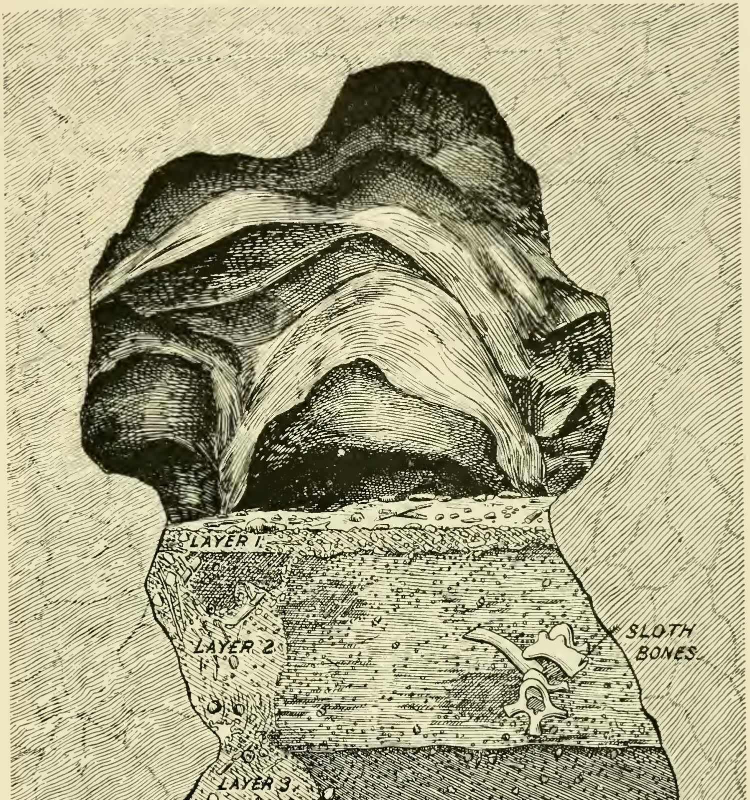


FIG. 4.—Diagram showing a vertical section of the gallery in Big Bone cave where the sloth bones were found. Layer 1 (2–3 inches), disturbed surface rubbish with charred torch ends. Layer 2 (2 to 2½ feet), dry loose rat excrement, animal and vegetable remains, etc., with sloth bones. Layer 3 (1 foot), crusted lower portion of rat excrement and vegetable remains formed before the advent of the sloth bones. Layer 4 (of undetermined depth), loose pieces of nitrous clay, dry and hard, mixed with manure. The disturbance resulting in the intrusion of torch ends and other objects into the deposit as far as Layer 4, caused by burrowing rats, is seen against the left cave wall.

3, and hence to the later time belong the sloth bones here shown. One after another they were found in the dry manure, which, lying invariably under Layer 1 above described, I have called

LAYER 2.

(2 *to* 2½ *feet thick. See Fig.* 4.)

As we worked forward through this layer with shovel, hands and trowel to where it thinned out and the saltpetre earth now removed had formed the foothold beyond it, we found it to consist almost entirely of well-preserved, dry excrements of the cave rat, *Neotoma magister*, which, intermixed in lesser quantity with coprolites of porcupines, *Erethizon dorsatus*, formed the conspicuous ingredients of the mass. In consistency like a bin

FIG. 5 (x ½).—First bone found (in Layer 2, depth about 18 inches), epiphysis or unknitted end of the humerus of a young sloth, Megalonyx. Photographed, resting upon the characteristic rubbish of Layer 2 found around it. 1. Bat's jaw, *Adelonycteris fusca*. 2. Hickory nut and fragment gnawed by rodent, *Hicoria glabra*. 3. Excrement of large mammal, possibly sloth. 4. Felted hair of bats, rats and porcupines mixed with a woolly fur, possibly belonging to the sloth itself. 5. Bones of the bat, *Adelonycteris fusca*. The background is composed of a mass of dry coprolites of cave rats, brown dusty earth, and fragments of hard cave clay, "petre dirt."

of oats, the deposit answered every disturbance with a cloud of pungent dust. Nuts, sticks, fur and moss were easily seen in it by candle light, but more minute search in the cave and a subsequent study of the specimens preserved, revealed at various points, the seeds, grass, bark, leaves, hair and small botanical fragments described later. In the midst of this interesting rubbish, often in contact with seeds, nuts and hair, appeared the twelve sloth bones here shown, protruding from the vertical side of the trench at depths of from eight to fourteen inches.

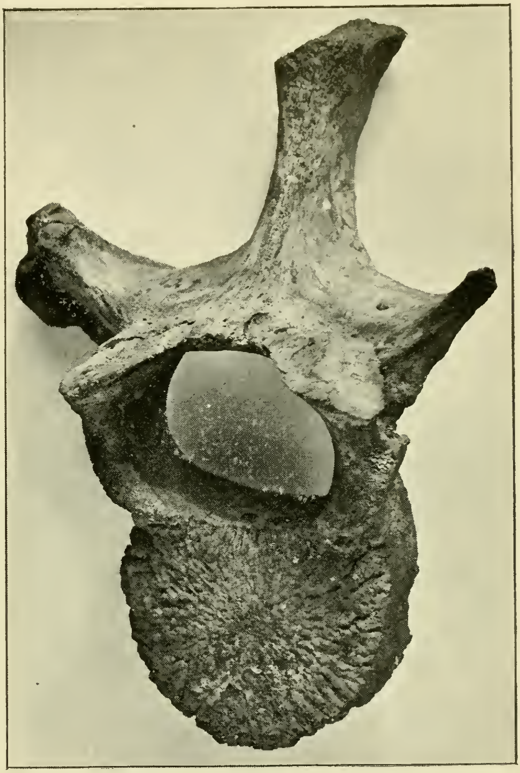


FIG. 6 (x ½).—The second bone found (in Layer 2, depth 1 foot 8 inches). Dorsal vertebra. A minute fragment of attached cartilage is not visible in the photograph. The marks of gnawing are upon the opposite side of the specimen.

No fear of breaking them, hard, dry and strong as they were, and I question whether they needed the dose of hardening solution which all but four of them have since received, and which has somewhat discolored them. In the dusty dimness we saw the cartilage, marked the signs of rodent gnawing,[1] and numbered each bone with India ink as it came out.

[1] The bone gnawing of rodents, done with their incisor teeth, often characteristic of bones found by me in American caves, differs greatly from the traces of mastication of the larger carnivoras. The latter, as dogs for instance, working sideways with

The first bone found (See Fig. 5) was an epiphysis of a humerus. Then came a well-preserved vertebra No. 2 (see Fig. 6), found at a depth of one foot eight inches below the surface and one foot from the right wall of the cave. The small coprolites touched it on all sides. Just above it lay a small twig of wood, and close to it several bones of bats, described later, while both above and below it we noticed wads of fine hair. The deposit was exceedingly dry, and its removal filled the cave with suffocating dust clouds. Immediately in contact with bone No. 2, as we worked horizontally into the bank, lay bones Nos. 3, 3½ and 4, two unseparated vertebræ with a loose epiphysis resting between them (see Figs. 7 and 8), directly under which we found two gnawed hickory nuts and an acorn.

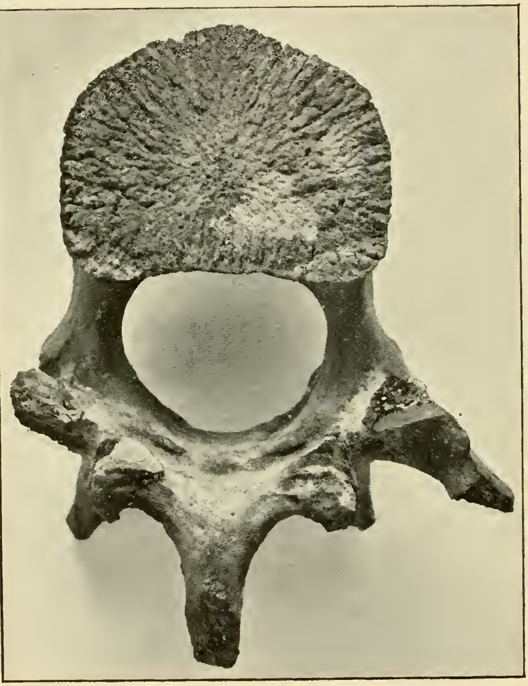


Fig. 7 (x ½).—Third bone found (in Layer 2, depth 20 inches). Dorsal vertebra. Signs of rodent gnawing not shown in photograph. Cartilage is seen attached to the base of the right projection.

As we advanced vertically into the manure, another vertebra, the fifth bone found (see Fig. 9), bone No. 6, the heel bone (calcaneum) (see Fig. 10), and bone No. 7 (the astragalus), (see Fig. 11), were revealed lying but a few inches apart. With deep interest I removed them. Just below the fifth bone, at which point the

their sharp canines and edged molars, dent the bones, or tear their corners irregularly, while the rodents furrow the points of vantage neatly, with numerous unmistakable parallel grooves, resembling the work of a coarse file held evenly.

deposit had hardened considerably (Layer 3) and was mixed with fine pieces of saltpetre earth, another acorn was found, and still another under the astragalus.

On that day, May 6, 1896, at 3.15 in the afternoon, with the wind blowing from the north, a slight draught of air wafted the currents of dust inward as we worked, while, to testify to the open communication of that part of the gallery and the outer world by means of the roof holes, a small cricket appeared, crawling upon the disturbed earth as we worked at the third bone.

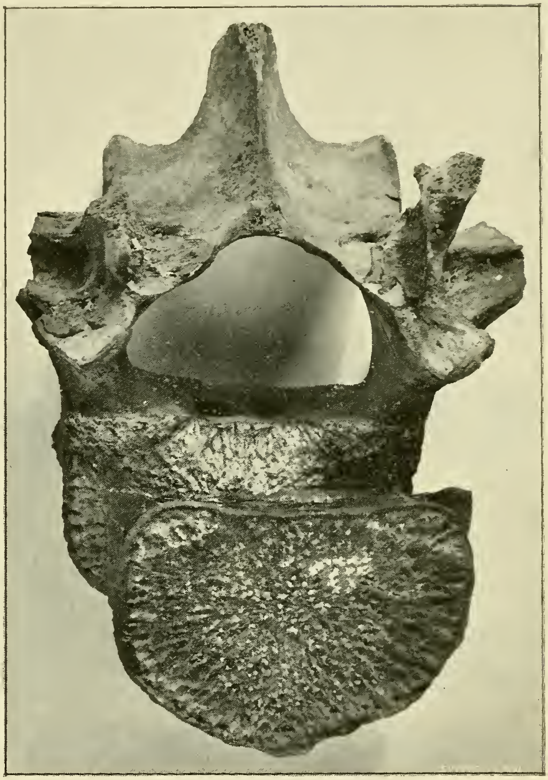


FIG. 8 (x ½).—The fourth bone found (in Layer 2, depth 20 inches). Dorsal vertebra and its loose epiphysis (unknitted plate), illustrating, because not yet ossified together, the undeveloped backbone of a young animal. The photograph fails show the signs of rodent gnawing and the bits of cartilage attached to the bone below the orifice.

A considerably gnawed rib fragment, (see Fig. 17), was followed by a loose epiphysis (see Figs. 12 and 13) and a final vertebra, the tenth bone found (see Fig. 14), lay against the rock wall on the right, not much more than eight inches below the surface, where, close to the top of the deposit and still against the wall, the wads of hair were best preserved. Here also were found a gnawed butternut, several pieces of grass, several small bat bones and dung as usual. The position of these latter objects close to the wall caused us to suspect that they had slid down from the surface, just as close to the left side twigs of leaves had probably been intruded in the rat holes. But the objects found at or below the position of the other bones we regarded as of equal age with them, and as truly indicative of the nature of the layer.

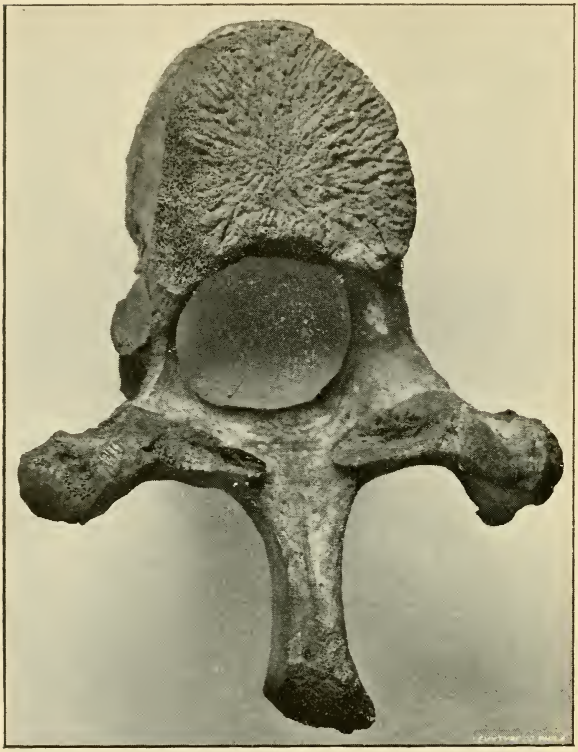


FIG. 9 (x ½).—The fifth bone found (in Layer 2, depth about 14 inches). Dorsal vertebra. The signs of rodents gnawing, clearly visible in the original, show faintly on the left projection. The cartilage shows indistinctly in the illustration on the upper surface of the left circular plate below the large orifice.

Our observation of the position of all the bones showed that they were not (with the exception of the two vertebræ and epiphysis (Figs. 7 and 8) in skeletal order: several epiphyses were loose; the calcaneum (heel bone) lay close to the vertebræ; the single rib found was broken and turned. Unquestionably the bones had been dragged and twisted out of place (inferentially by the gnawing rats or the porcupines) since their deposition. Some

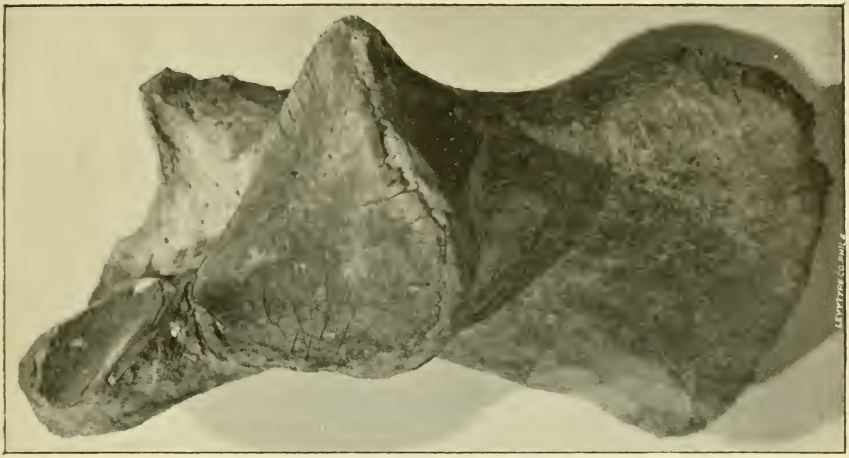


FIG. 10 (x ⅔).—The sixth bone found (in Layer 2, depth about 1 foot). Calcaneum (heel bone) of the extinct sloth Megalonyx. The cartilage (of a bright red toning into yellow in the original) rests as a thick film, considerably cracked, on the left articular face. Marks of rodent gnawing are shown around the lower circumference.

FIG. 11 (x ⅔).—The seventh bone found (in Layer 2, depth about 1 foot). An astragalus (joint or hinge bone of foot). A layer of cartilage (yellowish red in the original) covers the round face and protrudes in brittle flakes from the hollow.

FIG. 12 (x ⅔).—The ninth bone found (in Layer 2, depth about 1 foot). Two vertebral epiphyses indicating, because unwelded upon the larger bone, a young animal. The cartilage is plainly seen above the break.

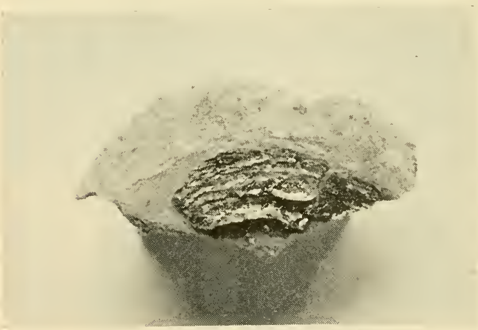


FIG. 13 (x ⅔).—The ninth bone found (in Layer 2, depth about 1 foot). Fragment of the vertebral epiphysis shown in Fig. 12. The attached cartilage is plainly seen. The color of the latter in the original is semi-translucent red.

may have been carried away to hidden crannies through burrows noted later communicating with the rubbish.

Long before we had pulled the last bone out of the dust, our attention was attracted to the lower or older portion of the manure, which, owing to its peculiar consistency, I have called

LAYER 3.
(1 foot thick.)

In it we observed no porcupine quills or tufts of fur, and for the reason below stated suspected that this lower subdivision of the dry excrement had become hardened and caked together just under the bones, into what it seemed reasonable to suppose had constituted the foothold of the cavern when the extinct animal appeared. Objects found in it, therefore, a further series of nuts, seeds, twigs, leaves, bat jaws, and fur described below, together with the dry carcass of the window fly, were to be reasonably regarded as older than the sloth.

How may we better account for the character and position of this crust, than by supposing that it represented that portion of the once lower floor where the carcass of the animal had for a time rested and into which the juices had filtered, caking together the coprolites during the consumption of the flesh by rats and porcupines?

FIG. 14 (x ½).—The tenth bone found (in Layer 2, depth about 8 inches). Dorsal vertebra more wasted than most of the other specimens. Discolored by a preservative preparation applied since its excavation. The signs of rodent gnawing are not shown in the photograph.

This not improbable suspicion was strengthened when we considered the number of bones found at the spot, not simply the twelve exhumed by us, but those previously excavated by Priest and Johnson, now in Prof. Safford's possession, and we may add the eighteen other remarkable cartilaginous specimens, presumably from the same spot, at the

Academy of Natural Sciences. If the whole combined series fails to duplicate or contradict the construction of a single fossil sloth skeleton, then all, because all indicate a young animal, and because all show cartilage as no other sloth bones elsewhere found have yet done, can be reasonably referred to the same individual animal. Many other bones, originally near or upon the surface, may have been removed by Indians or carried away by saltpetre diggers and lost. Rats may have made off with others. And, notwithstanding the fact that the sets belonging to the Academy and Prof. Safford, together with my specimens, may fail to reconstruct the animal's skeleton, the three sets together include enough bones to indicate that the creature had once lain there in the flesh. Because the tooth marks seem to refer to the work never of carnivora, but always of rodents, less to the efforts of large than of small animals not strong enough to have carried a skull such as Priest found, or a scapula like that at the Academy, from any other resting place in the cave, it seems reasonable to suppose that the bones reached their position by the most natural of agencies: that the sloth, lost or overcome by sickness in the darkness, had lain down to die at the place in question.

Reasonably doubting that it had shambled into the cave after the helpless club-footed manner of the modern Ai or Unau, shall we speculate further and imagine that the animal, less clumsy and sluggish than its modern South American relatives and presumably herbivorous from the structure of its teeth, was attracted to the spot by the smell of grass and leaves, brought thither by porcupines and rats? If not, we must believe that its choice of a deathbed in the only rat den in that part of the cave was a coincidence. But, however the position of the bones is to be accounted for, let us believe that if the carcass lay upon the manure, the number of visiting omnivorous rodents increased until the process of devouring the flesh had been succeeded by the gnawing of the bones.

If these suggestions explain how the bones came to be where we found them, we next ask, How old are they? When did they reach their position? An inquiry above all depending upon the study of the objects dug out of the earth with them. These are to be divided into three classes: First, *objects of later age than the bones, or of doubtful antiquity;* second, *objects as old as the bones*, and third, *objects older than the bones.* To the first class belong the torch ends of cane, *Arundinaria tecta*, hazel; fragments of clay, coprolites, and bits of charcoal, mentioned above, as belonging to Layer 1, and, second, objects artificially intruded into Layer 2.

Objects of Later Age Than the Bones, or of Doubtful Antiquity.

The hoarding habit of the underground rat had helped our investigation at Big Bone cave, but his burrowing perplexed and vexed us, confronting us with one of the dangers that often threaten exact observation in caves. The slowly formed accumulation of dry excrement had been undermined and disturbed by the tunneling of its makers against the right and left walls, where several rat holes were revealed by a variation in the texture of the neighboring layer. Pushed and wadded into these burrows (see Fig. 15) we

FIG. 15 (x ½).—Specimens of displaced rubbish found stuffed into and filling the rat holes. 1, 2 and 3. Burnt sticks, pieces of charred cane, *Arundinaria tecta*, and charred hazel twig, *Corylus americana*, representing the ends of burnt-out torches cast away by white men or Indians, often found at a greater depth in the layer than the sloth bones, having been intruded into the burrows from the surface by small animals.

found a bunch of moss, *Hypnum;* ten twigs from three to eight inches long, charred at the ends and evidently the remnants of torches, used by Indians or white men, of the hazel, *Corylus americana;* five fragments, one of them charred and three inches long, of resinous yellow pine, *Pinus mitis ;* a fragment of charred cane stalk, *Arundinaria macrosperma,* and another twig about eight inches long, not burned, of the cane, *Arundinaria tecta ;* a gnawed pig nut, *Hicoria glabra,* and a shellbark, *Hicoria ovata;* a piece of hickory nut, *Hicoria minima ;* a chokecherry stone, *Prunus virginiana* Linn.; a piece of hazel nut, *Corylus americana ;* a fragment of an acorn of the pin oak, *Quercus palustris,* and three pieces of winged seeds of the blue ash, *Fraxinus quadrangulata,* besides a piece of bark, probably hazel, and fragments of unidentified grass and bark. Besides these botanical specimens kindly identified (with all others referred to in this paper) by Mr. Stewardson Brown, of the Academy of Natural Sciences of Philadelphia, Mr. S. N. Rhoads, and Dr. Harrison Allen, of the Academy, have further settled the identity of twenty quills of the porcupine, *Erethizon dorsatus,* with its numerous excrements, (See Fig. 16) and a piece of hair, which had found their way into the holes, besides the upper jaw with portions of the skull of a bat, *Vespertilio gryphus ;* and a lower and upper jaw, with teeth and cartilage attached, of a larger bat, *Adelonycteris fusca.* More excrements of porcupine seemed to have worked into the choked-up holes than were observed in the undisturbed portion of the layer, while with them was found a fragment of the brain case of a large mammal, smaller, according to Mr. Rhoads, than an adult bear. If this small specimen, not an inch in length, cannot be regarded as a portion of the remains of the Megalonyx, it represents the only trace of any

FIG. 16 (actual size).—Quills of the porcupine, *Erethizon dorsatus,* found with other intruded rubbish at various depths in the rat holes. No signs of the porcupine were found in the lower part of the manure (called Layer 3). Coprolites of cave rats and pieces of clay form the background.

other large animal that we, or our guides previously, were able to find at the spot. But the objects found in the rat holes could not reasonably be associated with the bones. Though positively testifying to the presence of men as well as of animals in the cave, the charred torch sticks and other articles had been transported from their original position in the manure; and while it was certain that objects found in the superficial Layer 1 (including the torch ends, see Fig. 2), were more modern than the sloth bones, the rat-hole specimens had lost their true time relation to the sloth. If not all intruded downward from above, and so presumably more modern than the bones, the collective age of all the specimens was doubtful and offered no evidence of the contemporaneity of man and the Megalonyx.

On the other hand, no sign of disturbance was presented by the texture or contents of the middle portion of Layer 2. There the objects found at various points, and particularly close to the bones, seemed fairly to be regarded as ingredients of the deposit. Undoubtedly they represented plants and animals in existence at the time the bones had been deposited.

As we dug on with shovel, hands and trowels, narrowly observing that part of the manure (in many cases preserved by us in bags) lying in immediate contact with the bones, our work revealed by reasonable inference a series of

Objects as Old as the Bones.

In the handfuls of refuse removed from close proximity to the sloth bones and preserved in bags were found, as identified by Mr. Rhoads (see Fig. 23), numerous tufts of the fur (also found in the rat holes), a comparatively large excrement quite unlike the other coprolites in size and shape, attributed by Mr. Rhoads to an herbivorous animal (see Fig. 17 object 8 and Fig. 5 object 3). Of the common coprolites previously mentioned, the larger and scarcer ones containing fine shining particles of undigested hulls and skins of nuts, showed that the porcupine (*Erethizon dorsatus*), guided by other senses than sight, had been continually present during the formation of Layer 2. So testified a hair from the back of one of these animals (Fig. 17 object 16).

Eight beautifully preserved minute jaws and several little bones were identified by Dr. Harrison Allen as the remains of two kinds of still existing bats, *Adelonycteris fusca* (see Fig. 17 objects 17) and the smaller *Vespertilio gryphus.* Unfossilized and fresh look-

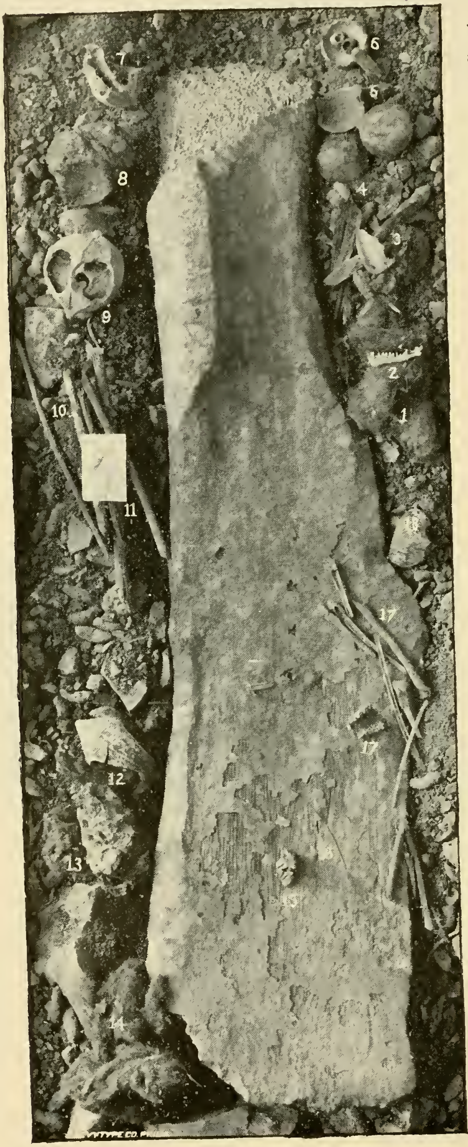


FIG. 17 (x ½). — Eighth bone found (Layer 2, depth about one foot). A rib showing signs of rodent gnawing along its edges. A part has been broken off at either end, and the specimen appears to have been much dragged through the refuse. Its color is light brownish yellow. No cartilage was attached to it. The rubbish of Layer 2 forms the background. Noticeable ingredients of the layer are ranged on either side of the bone. 1 and 14. A felted mixture of rodent hair with woolly fur, possibly of sloth. 2. Bat jaw, *Adelonycteris fusca.* 3. Beech nut, *Fagus americana.* 4. Winged seeds of blue ash, *Fraxinus quadrangulata.* 5. Acorns of red oak, *Quercus rubra.* 6. Acorn cup of Spanish oak, *Quercus digitata,* sunflower, *Helianthus annuus* and alder, *Alnus incana,* seeds. 7. Hickory nuts, *Hicoria minima.* 8. Coprolite of large animal, possibly Megalonyx. 9. Gnawed shellbark, *Hicoria ovata.* 10. Twigs. 11. Fragments of skein of maize silk, *Zea maiz,* excluded from the evidence for reasons given in the footnote to page 63. 12. Gnawed hickory nut. 13. Another coprolite of large animal. 15. Jaw with teeth of cave rat, *Neotoma magister.* 16. Porcupine hair, *Erethizon dorsatus.* 17. Bat jaw and bones, *Adelonycteris fusca,* with twigs of dogwood, *Cornus alternifolia,* just below. 18. Hazel nut, *Corylus americana.*

ing, the bones, according to Dr. Allen, represent individuals which had fluttered through the congenial blackness of the gallery in geologically recent times, though we admit that the species referred to are ancient and probably existed at the epoch called post-glacial.

FIG. 18 (actual size).—Specimen of Layer 2. An acorn cup of the pin oak, *Quercus palustris*, and a gnawed mocker nut, *Hicoria alba*, rest upon fragments of cave clay and a mass of dry rat manure.

In the very close neighborhood of the bones, as further identified by Mr. Stewardson Brown, we found fragments of the acorns of the red oak, *Quercus rubra* Linn. (Fig. 17 object 5), and of the white oak, *Quercus alba* Linn.; an acorn cup of the pin oak, *Quercus palustris* Duke (see Fig. 18); half of a nut gnawed by rodents of the thick-shelled, small-kerneled mocker nut, *Hicoria alba* Linn., Br., (see Fig. 18) several gnawed nuts of shellbark, *Hicoria ovata* Mill, Br., and the gnawed nut of the butter nut, *Juglans cinerea* Linn. With these lay several fragments of winged seeds of blue ash, *Fraxinus quadrangulata* Mich. (see Fig. 19 and Fig. 17 object 4); two seeds of the horn beam, *Fraxinus caroliniana* Walt.; a piece of bark of the chokecherry; a seed of the gum *Nyssa sylvatica*; two small twigs of dogwood, *Cornus alternifolia* Linn.; fourteen little fragments of sticks and leaves and several pieces of bark undetermined, together with two wild cherry stones, *Prunus pennsylvanica* Linn.; while recorded as exactly under one of the sloth bones we pulled out a seed of the alder, *Alnus incana* Linn. (see Fig. 20), and another of the horn beam, *Carpinus caroliniana* Walt., with a nut of the beech, *Fagus americana* Sweet (Fig. 19).

FIG. 19 (actual size).— Rat excrement, clay and vegetable rubbish characteristic of Layer 2. Against two fragments of the winged seeds of the blue ash, *Fraxinus quadrangulata*, and inside of a gnawed acorn of the red oak, *Quercus rubra*, rests a beech nut, *Fagus americana*. These bones were unearthed near the large bones and had probably been brought into the cave for food or nest building by the cave rat, *Neotoma magister*.

There was no reason for doubting that these objects had reached their position at or about the time of the deposition of the sloth bones. Many of the nuts had been gnawed by cave rats (see Fig. 17 object 9), *Neotoma magister*, and the same agile pilfering animal, helped possibly by the porcupine, had doubtless dragged in by way of the roof holes, whether for nest building, for food, or in pursuance of its eccentric hoarding habits, many of the other objects scattered at various points in Layer 2. In this mass of excrements of the cave rat, which, dry as they were, were crushed with some difficulty between the thumb and finger, together with the lesser porcupine coprolites, we found a hair from the back of the porcupine and a portion of the right side of the upper jaw with molar teeth of the cave rat (see Fig. 17 objects 16 and 15). Scattered irregularly through the layer, as identified by Mr. Thomas Meehan and Mr. Brown, lay an acorn cup of the Spanish oak, *Quercus digitata* (Marsh) Sud. (see Fig. 20); two fragments of acorns of the pin oak, *Quercus palustris;* a seed of the horn beam, *Carpinus caroliniana* Walt.; and fragments of seed of the blue ash, *Fraxinus quadrangulata* Mx.; a fragment of hickory nut, *Hicoria minima;* of hazel nut, *Corylus americana*, Walt. (see Fig. 17 object 18), and of beech nut, *Fagus americana* Sweet (see Fig. 19); a valve of the hop horn beam, *Ostrya virginica* Willd.; an awn of wild rye or lyme grass, *Elymus* Linn.; and a piece of the stipe of common brake, probably *Pteris aquelina* Linn. With these were two seeds of the blue ash, *Fraxinus quadrangulata*, others of the horn beam, *Carpinus caroliniana* (see Fig. 21), alder, *Alnus incana* (see Fig. 20), beech, *Fagus americana*, and gum, *Nyssa sylvatica* (see Fig. 21), two wild cherry stones, *Prunus pennsylvanicus*, a piece of chokecherry bark, twigs of dog wood, *Cornus alternifolia*, fragments of sticks (see Fig. 17 object 10) and leaves, and, according to Prof.

FIG. 20 (actual size).—Characteristic portion of the rubbish of Layer 2. Coprolites of the cave rat and pieces of dry clay form the background. The vegetable remains carried into the cave by rats and porcupines were found buried in the undisturbed layer near the sloth bones. 1. Acorn cup of Spanish oak, *Quercus digitata*. 3. Two seeds of the alder, *Alnus incana*, and, 2. Seed of the sunflower, *Helianthus annuus*, a plant supposed by botanists to have been transplanted by Indians from South America or the trans-Mississippi plains. Omitted from the evidence for reasons given below.

Heilprin, one of the bead-like stem segments of a crinoid characteristic of the carboniferous limestone of the cave walls.

FIG. 21 (actual size).—Objects which were imbedded in the cave earth about the time that the sloth bones reached their position. 1. Gnawed seed of the gum *Nyssa sylvatica*, and 2, gnawed seeds of the hornbeam, *Carpinus caroliniana*, found in the unhardened later part of the manure (Layer 2) around the resting place of the sloth. Cave rat coprolites and characteristic ingredients of Layer 2 in the background.

Judged by this botanical association, the age of the sloth remains was that of the flora of the surrounding hills, and that had not changed since seeds, nuts and bones came together. These specimens of well-known trees and plants common to the forest of eastern North America still flourished upon the mountain above us.

But over and above the general significance of this fact, two objects discovered—the *fur* and the *large coprolite* had a particular bearing upon the investigation.[1]

FIG. 22 (actual size).—Objects which reached their position in the cave earth before the advent of the sloth bones. 1. Jaw and bone of the bat, *Vespertilio gryphus*. 3. Hair of the cave rat, *Neotoma magister*, and 2. Skein of maize silk, *Zea mais*, excluded from the evidence for reasons given in the footnote.

[1] Not in the underground darkness, but seven months later, during the examination of the contents of two muslin bags, brought from the cave, labeled Layers 2 and 3, and finally placed in glass jars, I found (as identified by Mr. Brown) two fragments of maize silk, *Zea mais*, (see Fig. 17 object 11, and Fig. 22 object 2), and a seed of the sunflower, *Helianthus annuus*, (see Fig. 20 object 2). If unquestionably bedded as deeply in the undisturbed deposit as the sloth bones, these specimens might well have testified to the existence of an aboriginal cornfield or sunflower plantation rifled by cave rats on the hill above, or in other words (if with recent investigators we suppose maize to have been indigenous to southern Mexico, the sunflower to South America or the trans-Mississippi plains, and disseminated North and East by Indians), to the contemporaneity of the red man with the sloth. But as several ears of corn in the husk came from Tennessee in contact with the specimen bags, there is a chance that skeins of the former, clinging to the outside of the muslin bags may have fallen into the glass jars, when the latter were filled from the bags—while a mischance in the process of affix-

FIG. 23 (actual size).—Mass of felted hair of rodents, together with a fine wool belonging possibly to the extinct sloth, found scattered through Layer 2, and often near the large bones. On this lies a jaw from the same layer of the bat, *Adelonycteris fusca*. The background shows the mass of rat manure and clay fragments characteristic of Layer 2.

Sometimes close to the bones, and generally scattered through the whole mass of manure in Layer 2, felted like tufts of carpet dust in an unswept room, lay wads of hair or fur (see Fig. 23, Fig. 5 object 4 and Fig. 17 object 14), exceedingly fine, slightly crinkled, with a reddish brown color, possibly due to contact with the cave earth. To what animal shall we attribute them? Certain fine bits may, according to Mr. Rhoads, be referred to the bat and a few straight hairs to the rat or porcupine. But as none of the rat fur has this crinkle, and as the under fur of the porcupine, according to Mr. Rhoads, is coarser than these specimens and always straight, this crinkled cave wool is attributable to neither animal. Shall we suppose it to be the under fur of the buffalo, or of any of the animals of the outer forest carried down into the cave in predominant quantity by rats? Is it sloth fur, and if so, why its extreme fineness? Where are the large, limp hairs, flattened in appearance and grayish white in color, characteristic of the living sloths? Shall we fancy the fossil sloth fine-furred as a seal? Yet if this discovered fur, which in all reason is contemporary with the sloth bones, be not sloth fur, what became of the sloth fur if the animal, as we suppose, perished here?

Leaving the significance of the fur in doubt, we are left to account for the comparatively large excrement of a herbiverous animal, likewise found in Layer 2, and altogether too large for the porcupine or cave rat (see Fig. 17 object 8 and Fig. 5 object 3). Because no other trace of a herbiverous animal of the size indicated was observed at the spot, and because of the herbiverous character of the sloth itself, it has seemed to Mr. Rhoads and myself possible to refer it, modern as it looks, to the latter mammal rather than to

ing labels makes it doubtful whether the sunflower seed belongs to Layer 2, or came from a rat-hole. For these reasons, I abandon the hope of positive demonstration involved in the presence of the sunflower (used by Indians for food and oil, and of maize, his favorite plant), that sloth and Indian were contemporaries at Big Bone cave.

the exceptional presence of any other grass-eating creature at that part of the cave. On the other hand, it appears small for the great sloth, while its unbroken contours infer that it must have been transported when dry and hard if we are to ascribe it to the deer or any animal of the outer forest, and suppose that the hoarding rat carried it down the roof holes into the cave.

In the compact lower portion of the manure called Layer 3, forming, as before described, a crust suggestive of an older floor immediately under the bones, we found what by a reasonable inference were regarded as

Objects Older Than the Bones.

Here in the dense mass of rat excrement, rested a lower jaw of the bat, *Adelonycteris fusca* (see Fig. 25 object 7), as to which, in completing the list of bat remains found in the cave, Dr. Allen says that the bats here described seem larger than our common eastern forms, though no marked variation in bats has been observed since the Pleistocene.[1] Not far from this, and as kindly identified by Mr. C. M. Johnson, of the Wagner Institute, lay a well-preserved dry carcass of the small "window" fly (see Fig. 24), common in the United States, first described in America by Say, in 1828, as a new species, *Scenopinus pallipes*, but afterwards recognized as identical with the European *Scenopinus fenesartlis* Linn., the window-haunting adult insect of the so-called carpet worm. Entomologists have left us in doubt as to its life and habits, but we may suppose that its food quest led it so far under ground as a consumer either of decayed wood, of dried wooly or animal matter (like carpets under which its thin larvæ are often found), or according to Willaston, of the minute *tinidæ*, or the true wool-devouring moths, *psocidæ*, who would have attended the decomposition of animal skins and furs at the spot. However the fly's visit to the subterranean darkness is to be accounted for, there can be little doubt that it came down through the roof holes like the cricket above mentioned,

Fig. 24 (actual size).—Dry carcass of the window fly, *Scenopinus fenestralis* Linn., embedded in the cave earth before the sloth bones reached their position.

[1] Of the few fossil bats found in America, Lund discovered four species of *Vampyrus*, one species of *Molossus* and one species of *Peropteryx* in Pleistocene

while its position at this depth in the cave refuse would testify to its presence in America before the coming of Columbus, were entomologists not sufficiently sure that it had not followed the white discoverers in their ships across the Atlantic.

Near by were found bedded in Layer 3 small pieces of bark, nuts, grass, twigs, and plant fibre unidentified, pieces of horn beam seed, *Carpinus caroliniana* (see Fig. 25 object 5); a seed of the blue ash, *Fraxinus quadrangulata;* two shellbarks, *Hicoria ovata*, and four fragments well gnawed by rodents; a gnawed bitternut, *Hicoria minima*, showing orifices for extracting the kernel made by a small rodent; and six pieces of the acorn of the pin oak, *Quercus palustris* (for all of which see Fig. 25). Judging by the absence

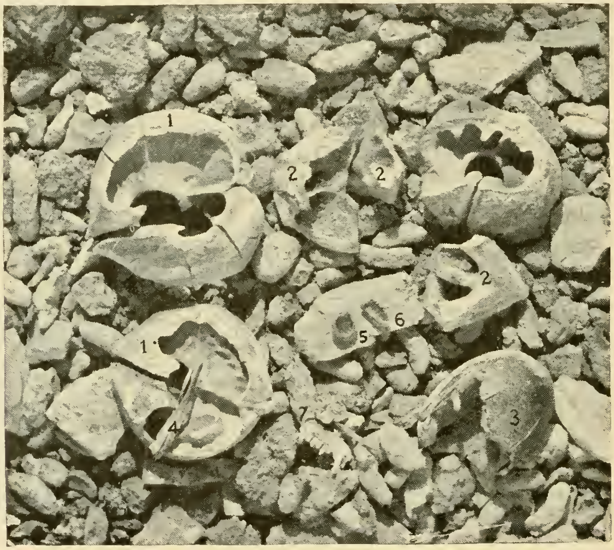


FIG. 25 (actual size).—Objects which reached their position in the cave earth before the advent of the sloth bones. 1. Shellbarks, *Hicoria ovata*. 2. Bitternut, *Hicoria minima*, gnawed by rodents. 3. Acorn of pin oak, *Quercus palustris*. 4. Fragment of seed of blue ash, *Fraxinus quadrangulata*. 5 and 6. Nut and seed of the hornbeam, *Carpinus caroliniana*. 7. Lower jaw and bone of the bat, *Adelonycteris fusca*. The background consists of the characteristic ingredients of Layer 3.

Brazilian caves; and Marsh gives two species of *Nyctetestes* and one of *Nyctetherium* from the Eocene of the United States (see *Catal. de Mamiferes*, Tronsaert, Paris, 1879, extr. *Rev. et Mag. de Zool.*, 1878).

of quills, hairs and coprolites, the porcupine had not visited the cave during the formation of Layer 3. Neither were we able to find in the latter layer the wads of fine fur so characteristic of Layer 2 above it, but if these were specimens of sloth fur, their absence is what we might have expected since the fur of the sloth could not well have been scattered over a lower depth than the resting place of its carcass. The absence of these ingredients, these differences in character, together with its position, were sufficient to assign an older date to the lower layer, whether its crusted consistency was due to the infiltration of animal matter or not. According to the order of formation of the different refuse, the lower layer preceded the upper, and the gnawed nuts, the seeds, the fly preserving intact its delicate wings, comparatively modern as they seemed, had reached their position before the deposition of the bones.

Faint from continual inhalation of the noxious dust, we had lost the energy to excavate to its bottom, the last and lowest layer,

LAYER 4,

(*Depth unknown.*)

a mass of fine water-laid clay, broken in lumps ranging in size from six inches to a quarter of an inch in diameter (see Fig. 26), covering the whole floor of the gallery and evidently the equivalent of the nitrous earth which had been elsewhere removed. By their laminated structure the lumps gave evidence of their aqueous deposition, while hard as they now were they dissolved immediately on immersion in water. Some pieces showed an irregular texture as of the caking together of various partially hardened muds, while others, in the opinion of Mr. George Vaux, Jr., revealed small fragments (irreducible by boiling in water), of adulterated carbonate of lime, probably aragonite. After digging several holes in the mass to learn that the manure had infiltrated downwards for at least two feet through

FIG. 26 (actual size).—Characteristic specimens (of Layer 4) under the sloth bones. Photograph of angular fragments of dry cave clay, "petre dirt," between which rat coprolites are seen. The fragments grew larger and were less mixed with manure as the excavation went deeper, but the bottom of this lowermost layer was not reached.

its interstices, we abandoned it where the configuration of the cave walls, widening as we went down into a crevice of unknown depth (see Fig. 4), rendered further work under the circumstances hopeless. We left with the reasonable inference that a depth of five, ten or fifteen feet would have laid bare the whole bottom, as it had been laid bare elsewhere in the gallery. Doubtless the process of drying, which succeeded the deposition of the layer by water, had broken it into lumps, between which the upper refuse, as remarked before, had penetrated, thus adulterating it without obscuring the fact that in its true constitution, for the eighteen inches examined, it contained no trace of man or animals.

Allowing the dust to settle for the last time, we turned away from the mysterious spot, and, threading our way wearily through the chilly gallery, came with sudden shock upon the dazzling glow and severe heat of a southern evening. With difficulty we toiled homeward, resting often in the warm woods.

At the last remaining point of significance we had examined layers which probably present all the evidence that will ever be collected as to the antiquity of the fossil sloth of Big Bone cave.

Let paleontology enlighten us as to the probable character and habits of this animal which we must reasonably regard as one of the common inhabitants of the American forest in Pleistocene times. Comparing the large vertebræ, the skull, the proportionately shorter claws and stouter limbs with the skeletons of the existing South American sloths, as here shown (thanks to the kindness of Dr. H. C. Chapman), we may well disbelieve that this animal hung, like the latter, back downward for days upon a single bough, or lagged in one tree or grove until moss formed upon its fur. How shall we imagine the creature, weighing from twelve to sixteen hundred pounds, moving from tree top to tree top in any known North American forest, when on the blowing of wind, according to the saying in Brazil, sloths travel. On the contrary, as the continual falling of so large an animal by the breaking of boughs is not to be imagined, we must deny the creature a strictly arboreal life, rather supposing, with Prof. Cope, that the boughs came down to the sloth than that the sloth went up to the boughs. In place of moss-covered clumps of motionless fur not easily distinguished from leaves, that a keen eye recognizes in South American tree tops, we fancy animals inhabiting the earth and proclaiming their presence by the crash of saplings and outlying boughs.

as, rising upon their hind legs or climbing to the forks of heavy trunks, they tear their fodder to the ground.

If they despised water, like the Ai and Unau, they licked salt, as their fossil bones bedded in the Petit Anse salt pit in Louisiana and the mire of Big Bone Lick testify. As terrestrial animals continually on the defensive against the foes of the forest, probably little less active than bears, the great sloths would hardly have rolled helplessly upon their backs when attacked like the Unau, or yielded up their dinner with a melancholy drone. On the contrary, though we must imagine them inoffensive and by no means agressive enemies of animals or man, the thrust of the powerful arm, and scratch with the claws that brought down saplings, might well have defended them against powerful and active foes.

A categorical demonstration that this individual animal was a contemporary of the geologically recent Indian in Tennessee must be abandoned. But the reasonable inference of such association remains. Though the human handiwork, in the form of charcoal and torch refuse (except the rat-hole specimens), lay really on the surface (Layer 1), from six inches to one foot above any sloth bone found; we may justly be satisfied with the recent significance, broadly regarded, of the whole record, and with the absence of plants and smaller animals of any extinct or positively ancient form.

Gradually a thin sprinkling of rat excrement upon the clay floor had thickened into a dry dense mass. Before the deposit had reached a depth of two feet, the sloth had appeared and perished, and while the duration of this manure-making process, which finally, rising round the bones, covered them to a depth of one foot or eighteen inches, cannot be safely guessed at in terms of centuries, there can be no doubt that it is geologically recent, and that its construction which preceded and followed the deposition of the sloth bones is continued by the visits of existing cave rats at the present day. The manure formed, the leaves, nuts, grass and seeds found their way in, without the interruption of any important interval of time or geological event changing the topography of the cavern. The roof holes had probably remained open continuously. The subterranean temperature of fifty-five degrees Fahrenheit, with an extreme dryness, had probably persisted. The same flora had continued to flourish upon the mountain. The same visiting animals had continued to find the same plant food, while the same bat species had sailed in from the open entrance.

Had these bones lain within reach of the percolating chloride of lime, this mineral filling the cavities vacated by animal matter might have hardened them as cave bones are often hardened, but lying where we found them we may well doubt whether they ever would have fossilized. Under such circumstances, let us believe that a nut, a seed, a leaf, or even a fly, would preserve the freshness of its structure for a long time, and hence that the interesting remains found with the bones may not be so modern as they seem. With this reservation, and without attempting to deal definitely with dates, it seems safe to class the evidence not only as geologically but as historically recent. Not more ancient in appearance, not more brittle than the bones of animals found by me in the Indian midden-heaps of several caves, the position of the bones in the upper and later part of the rubbish, their gnawed condition, and their association, as described above, offer nowhere a suggestion of great antiquity. Separated from all association with the remains of other Pleistocene animals, they fail to lend the color of antiquity to the situation. On the contrary, like the peccary bones found at Durham cave,[1] like the remains of tapir and mylodon discovered in Lookout cavern,[2] they seem modernized by their surroundings. Let us infer that we have found a species which, long surviving its day and earlier relationship, had become an anomaly; that we have modernized the fossil sloth, if we have not definitely increased the antiquity of the Indian hunter, whose first coming the animal doubtless witnessed in the woods of Tennessee.

1 An exploration of Durham cave by H. C. Mercer, Publications of University of Pennsylvania, Vol. vi. Ginn & Co., Boston, 1897.

2 Bulletin distributed by the Department of American and Prehistoric Archæology at the University of Pennsylvania. January, 1894.

ON NEW PALEOZOIC VERTEBRATA FROM ILLINOIS, OHIO AND PENNSYLVANIA.

(*Plates I–III.*)

BY E. D. COPE.

(*Read February 5, 1897.*)

The following pages contain descriptions of new and little-known species of Fishes and Batrachia from the Catskill and Coal Measure epochs. These are based on specimens which are for the most part contained in the private collection of Mr. R. D. Lacoe, of Pittston, Pa. Mr. Lacoe's collection is in this field, and in that of the fossil plants of the region in question, one of the best in existence. I have already described and figured from it the remarkable (?) Euryptoid, *Mycterops ordinatus*,[1] from the Coal Measures of Cannelton, Beaver county, Pa., and the *Holonema rugosa* of Claypole from the Catskill of Bradford county.[2] In the present collection I report the first Batrachian remains found in the Pennsylvania Coal Measures and describe a new genus of Stegocephali from Cannelton (Ctenerpeton). I also note the occurrence of Glyptolepis in the United States for the first time, and by it extend the range of the Catskill fishes in Wyoming county, Pennsylvania.

The occurrence of a large species of Cœlacanthus in the Mazon Creek, Ill., deposit is also shown by specimens in this collection.

PISCES.

HOLOPTYCHIUS SERRULATUS sp. nov., Pl. II, Fig. 1.

That the more distinct species of Holoptychius can be distinguished by their scales is the opinion of those palæichythologists who have studied them. The variety of such scales which is found in the Catskill beds of Pennsylvania and New York is considerable,

[1] Cope, *American Naturalist*, 1886, p. 1029, Pl. XV, Fig. 3.

[2] *Proceeds. Amer. Philos. Soc.*, 1892, p. 223, Plate VII, Fig. 2.

and I have endeavored to identify among them the species of authors. The *H. granulatus* of Newberry appears to be based on an inferior side of a scale of some species, whose true characters will remain unknown until the superior face is discovered. The following species seem to be well founded, and to differ as follows:

I. Basal part of scale smooth.

a. Ridges entirely broken up into tubercles .... *H. tuberculatus* Newb.

aa. Ridges partially broken into tubercles. *H. giganteus* Ag.

aa. Ridges not broken into tubercles.

Ridges moderate, inosculating, no intermediate tubercles......... *H. nobilissimus* Ag.

Ridges moderate, inosculating, small tubercles between the ridges proximally............................ *H. dewalkei* Loh.

Ridges moderate, not or little inosculating; no tubercles......... *H. americanus* Leidy.

Ridges moderate, parallel, no tubercles, small.. *H. radiatus* Newb.

Ridges very wide with fine grooves............ *H. hallii* Newb.

II. Basal part of scale with rows of tubercles.

Ridges subparallel; tubercles few, in a small tract; size small.... *H. flemingii* Ag.

Ridges coarse, inosculating, 25–30; tubercles less numerous, in 25–30 rows; large...................... *H. inflexus* Loh.

Ridges fine, inosculating little, 40; tubercles more numerous, in about 40 rows; large.................. *H. serrulatus* Cope.

III. Basal part of scale with coarse radiating ridges.

Distal ridges coarse, numerous, interrupted, passing gradually into the rather fine, proximal ridges which are not cut by cross ridges; large......................... *H. filosus* Cope.

IV. Basal part of scale with fine radiating and concentric ridges (Glyptolepis). Size smaller.

Distal ridges coarse, few, closely placed, without lines between; no radiating lines of tubercles.................. *H. latus* Cope.

Distal ridges coarse, more numerous, closely placed, without lines between; proximal radiating lines of tubercles, forming a fan. *H. flabellatus* Cope.

Distal ridges fine, with thread lines between, proximal radiating lines of tubercles....................... *H. leptopterus* Ag.

These species are distributed as follows:

Europe.	N. America.
H. nobilissimus.	*H. americanus.*
H. giganteus.	*H. giganteus.*
H. dewalkei.	*H. tuberculatus.*
H. flemingii.	*H. radiatus.*
H. inflexus.	*H. hallii.*
H. leptopterus.	*H. serrulatus.*
H. paucidens.	*H. filosus.*
	H. flabellatus.
	H. latus.
	H. quebecensis.

The *H. nobilissimus*, *H. giganteus* and *H. flemingii* are described by Agassiz in the *Poissons Fossiles*. The *H. tuberculatus*, *H. americanus*, *H. radiatus*, *H. hallii* and *H. giganteus* are described by Newberry in *The Paleozoic Fishes of N. America*. The *H. dewalkei*, *H. inflexus* and *H. flemingii* are described by Lohest in the *Ann. de la Soc. Geol. de Belgique*, t. xv, 1888. I described the *H. filosus* in the *Proceeds. Amer. Philos. Soc.*, 1892, p. 228. I now give descriptions of the *H. serrulatus*, the *H. latus*, and the *H. flabellatus*.

The *Holoptychius serrulatus* is based on a nearly perfect scale on a piece of brown argillaceous sandstone, from Mansfield, Tioga county, Pa., probably of Catskill age, although the color is rather unusual. The scale is represented by a very clean cast, of which a mould is figured in Pl. II, Fig. 2. The species is one of the large forms of the genus, the entire scale measuring about two inches in vertical diameter. In characters this scale is of the *H. flemingii* type, but the dimensions far exceed those of that species, resembling in this respect the *H. inflexus* of Lohest. It differs from that species in the more numerous, finer and less inosculating ridges of the exposed part, and in the larger batch of tubercles consisting of more numerous series, as pointed out in the analytical table. The distal ridges become more prominent near the centre of the scale, and terminate in some elevated portions which may be cut off from the remainder of the ridges, one or two of them becoming tubercles. The tubercles of the proximal part of the scale are sharply defined cones which increase in size as the series radiate from the centre towards the proximal border of the scale. The tract of tubercles extends over the entire base of the coarse ridges, and not over a part of them only as in the *H. inflexus* and is half as wide or more, than the width of the tract of coarse ridges. In this character and in the finer and less inosculating coarse ridges it differs from the *H. inflexus.*

Measurements.	MM.
Vertical diameter of scale	46
Longitudinal diameter of distal ridged area	22
" " " proximal tubercular area	11
Five coarse ridges in	5
Five rows of tubercles at base of tract in	4
Seven tubercles in	5

From the collection of Mr. R. D. Lacoe.

HOLOPTYCHIUS LATUS, sp. nov. Pl. II, Fig. 2.

Represented by the two scales from the greenish clay rock of Factoryville, Pa., said to be of Catskill age. The species probably belongs to the section Glyptolepis Ag., and is the first one found in this country. The distal part of the scale presents eight coarse ridges, which are separated by grooves narrower than themselves, and which do not inosculate. One of them appears to be interrupted. The central part of the scale is smooth, being only interrupted by the tube of the lateral line. The circumference from one side of the tract of coarse ridges to the other presents a wide band, which is primarily sculptured by fine ridges which radiate to the margin, and which are cut by concentric ridges of different degrees of coarseness, but which are coarser than the radiating lines. These characters are more exactly defined by the following:

Measurements.	MM.
Vertical diameter of scale	20
Transverse diameter of scale	17
Three distal coarse ridges	3
Seven proximal concentric ridges	3
Width of border of concentric ridges	6
Eight radiating ridges in	1

The scales of this species differ from all those hitherto described in the coarseness and small number of the distal ridges. Their parallel course distinguishes them from some species, and their failure to reach the center of the scale separates them from others. In size the type of the *H. latus* is smaller than the full-sized scales of the European species thus far described.

HOLOPTYCHIUS FLABELLATUS, sp. nov. Pl. II, Fig. 3.

Established on a nearly perfect scale from a green clay lamina from the supposed Catskill of the "Narrows" at Coxton, near Pittston, Pa. The scale is in perfect preservation, the finest details of the delicate sculpture being exactly preserved.

In the coarseness and parallelism of the distal ridges the scale represents those of the *H. latus*, rather than the *H. leptopterus*. In form the scale is longer than deep, and oval in outline, while that of the *H. latus* is as deep as long, and is rounded quadrate. Whether this difference depends on the position of the scale is not yet determinable. The border of the scale from one side of the distal ridges to the other, is occupied by a broad band which is marked by concentric grooves separated by wider convex interspaces. From the proximal end of the coarse distal ridges radiates a perfectly symmetrical fan of twenty-one ridges, each composed of a series of small tubercles, which increase in size to the end of the series. This fan measures half the long diameter of the scale between the coarse ridges and the proximal border. The entire surface, except that occupied by the coarse ridges, is sculptured by delicate line ridges and grooves of equal width, from the coarse ridges to the circumference, as in the *H. plicatilis*. The coarse ridges are twelve in number, and two of them are bifurcate. They are parallel in direction.

Measurements.	MM.
Vertical diameter of scale	11
Long diameter of scale	14
Three distal coarse ridges	2
Seven proximal concentric ridges	1.25
Width of border of concentric ridges	3
Eleven radiating ridges in	1

From the collection of Mr. R. D. Lacoe.

SAGENODUS OCCIDENTALIS Newb. *Rhizodus occidentalis* Newberry. *Report of the Geological Survey of Illinois*, Vol. ii, 1866, p. 19, Fig. 2.

Three species of Sagenodus have been distinguished by scales from the Carbonic system of Ohio and Illinois by Newberry, viz.: *S. occidentalis* and *S. reticulatus* from the concretions of the Coal Measures of Mazon Creek, Illinois, and *S. quadratus* from the Coal Measures of Linton, Ohio. The collection of Mr. Lacoe contains twenty-two scales with their reverses in clay concretions from Mazon Creek, and I have recognized the two species described by Newberry from this locality in nine of them. The remaining thirteen belong to several other species which differ widely in the size, form, and sculpture of the scales, no less than six species being apparently represented. Within the limits of these there is considerable variation, largely dependent on the part of the body from which the scale has been derived. They all present a more or less reticulate or tessellate structure, and a sculpture of very fine, closely placed lines, which radiate to the free border, the latter sometimes forming the only sculpture near the latter. This tessellate structure resembles that of the existing genus Osteoglossum, and its Eocene representative Dapedoglossus Cope. Dr. A. S. Woodward refers (*Catal. Fishes B. M.*) Newberry's species to the Dipnoans genus Sagenodus, and the species described below may be ultimately so referred. However, no teeth of Dipnoans have been found thus far in the Mazon Creek beds, while scales are abundant. The reference then remains uncertain, and the species should be determined for identification of the bed at other localities.

The species of the Lacoe collection differ as follows:

I. Concentric lines conspicuous; tessellation and radii not conspicuous.

Scales medium to large; subround.......... *S. occidentalis* Newb.

II. Concentric lines fewer, marginal; tesselation conspicuous, radiating from a center.

Scales medium to large, acuminate distad; tessellation very fine... *S. foliatus*, sp. nov.

Scales small to medium, elongate, subacuminate; tessellation elongate without regular radii or concentric ridges; center at extremity.............................. *S. reticulatus* Newb.

Scales medium to large, parallelogrammic; tessellation radiating, radii and concentric ridges extending to free edge; center at end.............................. *S. conchiopsis*, sp. nov.

Scales very large, elongate, tessellation confined to center, from which issue numerous well-spaced radii ...... *S. lacovianus*, sp. nov.

Scales medium, truncate; tessellation coarse, diamond-shaped, quincuncial. .... *S. quincunciatus*, sp. nov.
Scales medium, truncate; tessellation coarser parallelogrammic.... *S. browniæ*, sp. nov.

III. No concentric lines or center; a border of fine radii.
Very large, elongate, tessellation very fine.... *S. magister*, sp. nov.

IV. No concentric lines or radii; tessellation extending to posterior border.
Scales deep, smaller; center submedian; tessellation of medium coarseness.......................... *S. gurleianus*, sp. nov.

Of the *S. occidentalis* there are three scales (Figs. 1–2, 19–20–99), which agree well with the descriptions of Newberry. They evidently belong to a large species very distinct from the others here enumerated. I have not identified the *S. quadratus* Newb. found at Linton, O., in the Mazon Creek specimens. One scale presents a broadly truncate posterior margin, and it is even slightly concave. The size is rather large, appropriately to the *S. quadratus*, and the sculpture is strongly marked. I suspect that it is a scale from near the shoulder-girdle, and of entirely exceptional form. Newberry's type is incompletely preserved and described, and it will be necessary to secure other specimens from Linton in order for its full characterization.

SAGENODUS FOLIATUS, sp. nov. Pl. I, Fig. 1.

Founded on two scales in excellent preservation. These differ from those of all the other species here described in their elongate oval form, with subacuminate distal border. The proximal border is strongly convex. The sculpture consists, first, of a wide border of very fine radii, crossed by rather distant concentric lines; second, of a narrower band of coarser but rather close radii; and thirdly, of a rather large area of fine reticulations, of which the center marks the proximal fourth of the length of the scale. The marginal band is marked by a reticulation much coarser than that of the center.

Measurements.		MM.
Diameters of scale	vertical...........................	25
	longitudinal....................	39
Three tesseræ of area		1
Width of marginal band		6.5

Type No. F. 9 and 10, Lacoe's collection; Cotypes F. 53, 54.

SAGENODUS RETICULATUS Newberry, *Geol. Sur. of Illinois*, iv, 1870, p. 349, Pl. III, Fig. 9.

Pl. I, Figs. 2, 3.

I refer four scales to this species; one of them differing somewhat from the other three, a difference which may be due to difference of position. The characters in which all agree, are the very elongate form, with medium to large size, and the coarse and rather homogeneous tesselation, in which the areas partake of the elongate form of the scale. The distal border is narrowly rounded and is marked by a border of fine longitudinal striæ, which are not interrupted by concentric lines or reticulations. The single scale referred to has a lobe of the distal margin which projects beyond the remaining portion, but which has the sculpture identical with that of the latter. The proximal end is rounded in all and is marked in two of the scales by a few coarse radii. Three of them are further characterized by the presence of an oblique groove near one of the long margins. In two of them this groove cuts off a lanceolate area, passing from one long margin to the distal border, which is unsymmetrical by reason of its presence; in the scale above mentioned very much so. The center is near the proximal extremity, and is not conspicuously marked. It is possible that the grooved scales belong to the lateral line, but if so, the latter must be very irregular. The diversity in the grooves leads me to suspect, however, that all of them do not belong to the lateral line. This is a large species.

Measurements.

		MM.
Diameters No. 1 (groove incomplete)	vertical.....	19
	longitudinal.	36
Four tesseræ transversely measured in..............		3
Diameters No. 2 (complete with groove)	vertical.....	14
	longitudinal.	31
Three tesseræ (transversely measured) in...........		2

Nos. F. 175, 176; 57, 58; F. 55, 56; F. 59, 60; Lacoe collection.

Prof. Newberry, at the place above cited, includes in this species two scales of different form from those here described, and from the one which he represents at Fig. 9. I should have preferred to have retained his name for the species, to which these two scales belong, were it not for the fact that he states in his description that the *S. reticulatus* is characterized by the elongated form. "This is best shown," he says, "in some of the smaller specimens, which are more than twice as long as broad, and spatulate in outline." The two scales represented in Figs. 13, 14, belong probably to my *S. quincunciatus;* No. 13 is, however, larger than any scale of it which I have seen.

SAGENODUS CONCHIOLEPIS, sp. nov. Pl. I, Fig. 4.

Two scales of peculiar form represent this large species. They are parallelogrammic in outline, the extremities being about equally wide and equally moderately convex. There are two features of the sculpture which are conspicuous; first, the presence of minute striæ, both radiating and concentric, and second, the extension of the tessellate area to the edge of the scale, without border of striæ only as in the last species. The *S. conchiolepis* differs also from the *S. reticulatus* in that the terminal boundaries of the area, are also concentric, giving a characteristic appearance. The sculpture, as in the *S. reticulatus*, radiates from near the proximal end, which is not marked by radii.

Measurements.		MM.
Diameters No. 1	vertical at middle	20
	longitudinal	42
Tesseræ, width		.5 to 1.5
Diameters No. 2	vertical	13
	longitudinal	29

Type F. 15, 16; Cotype F. 17, 18; Lacoe collection.

SAGENODUS LACOVIANUS, sp. nov. Pl. I, Fig. 5.

A well-preserved scale indicates another species larger than the *S. conchiolepis*, and one which resembles more the *S. reticulatus*. The scale is an elongate oval with strongly convex extremities. Although one edge is damaged enough remains to show its parallelism to the opposite edge. The sculpture is also peculiar. The usual fine radiating lines are present, but there are no concentric lines, either fine or coarse, excepting a coarse one which is one-sixth the length from the distal border, and runs quite close to the long border. The areas are confined to a central tract, which extends from the proximal border over two-fifths the length from it. The space between the concentric ridge and the lateral borders is also segmented. The remainder of the surface is marked by rather close lines, which radiate from the reticulate center to the borders, and which are rarely connected by cross lines. A coarse groove enters proximad at one-third the width and extends across the scale towards the long margin without reaching it. This reminds of the groove in the *S. reticulatus*.

Measurements.		MM.
Diameters of scale	vertical	28
	longitudinal	57
Five interradial spaces, transversely measured, in		4

Nos. F. 47 and F. 48, Lacoe collection.

The only species with which it is necessary to compare this one is the *S. reticulatus*. The latter is without the radiating lines seen in this species, and the scales are more contracted distally; there is also no distinct center. The size is less, but that may be individual.

Dedicated to Mr. R. D. Lacoe, to whom science is indebted for the very fine collections he has made, and to the liberality with which he has furnished them to students for research.

SAGENODUS QUINCUNCIATUS, sp. nov. *Rhizodus reticulatus* Newberry, *Geol. Sur. of Illinois*, iv, Pl. III, Figs. 13, 14.
Pl. I, Fig. 6.

Represented by six scales, two of them in mutual relation. Size moderate; form wide, one extremity broadly truncate, the other narrowed oval. No concentric lines (an exception noted later) crossing the very fine radii. Reticulation coarse, quincuncial, areas diamond-shaped, the radial septa only continuing to the truncate or distal margin; the areas continued and becoming finer to the proximal or narrowed margin. No distinct center, unless the large tessellated area be considered as such. The areas are coarser towards the long margins. There are some lines parallel with the latter, which turn inwards parallel with the truncate border and then cease. In one of the scales these lines continue inwards so far as to constitute parts of concentric lines.

Measurements.		MM.
Diameters of scale	vertical	18
	longitudinal	28
Width of areas, from		.5 to .75

Three of the scales are smaller than the one measured. Type F. 39, 40; Cotypes 63, 64; 43, 44; 67, 68; 23, 24.

This species is figured very imperfectly by Newberry as above cited. His Fig. 13 presents a larger scale than any of this species which I have seen.

SAGENODUS BROWNIÆ, sp. nov. Pl. I, Fig. 7.

Represented by a single scale in excellent preservation. It approaches the form of those of the *S. quincunciatus*, but has a widely different sculpture. Scales as deep as long with truncate undulate free margin, and broadly rounded proximal margin. Minute longitudinal and no concentric striæ. Coarser sculpture, consisting of subparallel lines which radiate from a short transverse line near the proximal end to the proximal and distal margins, which are connected by transverse lines, which are not continuous with each other and hence not concentric. It follows that the areas are parallelogrammic. The cross-lines disappear near the distal margin, leaving only the radiating sutures.

This scale is wider in relation to its length than any of the species except *S. occidentalis* and *S. gurleianus*, and is more broadly rounded proximally, and more undulate distally than its ally, the *S. quincunciatus*. The areation is coarser than in any other species and of a unique pattern.

Measurements.		MM.
Diameters of scale	vertical	18
	longitudinal	21
Three areas measured transversely in		3

Type No. F. 13, 14.

SAGENODUS MAGISTER, sp. nov. Pl. I, Fig. 8.

Founded on two scales which exceed in dimensions those of any of the species here described. They differ somewhat in form, one being slightly truncate at both extremities, while the other is more regularly rounded. I regard the former as the type, but suspect that they belong to the same species, as the sculpture agrees closely.

There is the usual minute longitudinal striation; besides, there are no concentric lines, but a fine and irregular areolation extending over the entire surface, except in the type specimen for a short distance at the distal margin; in the other some of the coarse radii extend to the margin. There are coarse radii at the proximal margin in the type; in the other this edge is broken away. In both there is a very coarse areation along the long borders.

Measurements.

		MM.
Diameters of type	vertical	38
	longitudinal	60
Diameters of areas from		.5 to 1
Diameters of F. 7	vertical	36
	longitudinal	62

Type No. F. 5, 6; Cotype F. 7, 8.

SAGENODUS GURLEIANUS, sp. nov. Pl. I, Fig. 9.

This peculiar species is represented by a single scale. It is at least as deep as long, and the entire surface is covered with reticulations. The character of the sculpture is such that I cannot orient the borders of the scale. Its general outline is that of a very obtuse-angled equilateral spherical triangle. Along one of the borders the areation is more minute than along the other two, where it is rather coarse. In a large central tract the areation is intermediate, but as it is centrally placed, it does not aid in the orientation of the scale, as to the anterior and posterior borders; while the disposition of the areas indicates which is the vertical, and which the longitudinal diameter. There are apparently none of the fine longitudinal striæ usual in this genus, and there are a few concentric ones near the margin with coarse areas. The areolar septa are not regular except a few which are subradial to one of the subhorizontal margins.

Measurements.

		MM.
Diameters of scale	vertical	18
	transverse	17.5
Coarser areas		.75
Finer areas		.2

Type F. 21, 22. Lacoe collection.

This species is dedicated to Mr. W. F. C. Gurley, State Geologist of Illinois, to whom I am under much obligation for the opportunity of examining important material.

BATRACHIA.

CTENERPETON ALVEOLATUM, gen. et sp. nov. Pl. III, Fig. 1.

Char. gen.—Limbs present; neural spines and chevrons of caudal vertebræ fan-shaped. Ribs present, not alate. Abdomen protected by dermal scuta in series, which form chevrons directed forwards, which terminate on each side of the belly in a series of prominent, elongate and flattened scuta, which form a ledge or shelf on each side.

This genus is founded on a specimen on a block of coal shale which is so broken that the head is wanting, and no thoracic plates are preserved, although a considerable part of the right fore limb is present. A trace of bones of a hind limb appears, and it is probable that these members were present, but of small size. The affinities of Ctenerpeton are with Oëstocephalus, Ptyonius and Urocordylus, as indicated by the characteristic caudal vertebræ. It differs from the first two in the robust scales which protect the belly, and from all three in the presence of an external series of longer flat scales, which form a prominent border, perhaps more or less free, on each side. These resemble the closely placed teeth of a coarse comb, and give the name to the genus. I have not observed this character in any other genus of Stegocephalia.

Char. specif.—Each abdominal dermosseous rod consisting of three segments; the median, which forms the angle of the chevron, the intermediate, which is long and slender, and the marginal, which differs in form from the others. It is wider at the base, and is curved gently backwards, terminating in a gradually contracted obtuse apex. It is marked with delicate grooves which run out on the posterior margin, and on the extremity. The anterior edge is slightly overlapped by the posterior edge of the plate immediately preceding. The anterior plates of the external series are short and obtuse. The posterior edge of the rods of the median and intermediate series is impressed by a single series of small pits like the shallow alveoli of closely placed small teeth. The neural fans of the caudal vertebræ are considerably wider than the hæmal fans, and are divided nearly to the base by a shallow groove, which is not present on the hæmal fan. The fans are of about the same length, and about twice as long as the body of a vertebra. The marginal portion is marked with ten or a dozen short longitudinal grooves, which cut the truncate edge.

The ulna or radius is short, and there is no indication of osseous carpus. The digits are long and slender, and parts of four are preserved. The first and second phalanges are slender, subequal, and a little shorter than the metacarpal. The species had a short leg and a long foot. The only trace of posterior limb is a bone (perhaps both bones) of the leg. This is quite short, and in appropriate proportion to the fore leg, but the piece is too obscure for positive determination.

The general proportions are salamandrine with indications of the long tail which characterizes the group of which Urocordylus Hux. is the type.

Measurements.	MM.
Width of belly at middle	28
Length of median rod of ventral armature	6
" " intermediate rod of ventral armature	6
Width " " " " "	1
Length " external " " "	9
Width " " " " "	2
Length " (?) ulna	6.5
" " metacarpal	5
" " phalange i	3
" " " ii	2.5
" " (?) tibia	5.5
" " a caudal vertebra, body	4.5
" " " " neural spine	8
" " " " hæmal spine	7

From the Coal Measures of Cannelton, Pa.; from the collection of Mr. R. D. Lacoe.

This interesting batrachian is about the size of the *Oëstocephalus remex*, but it appears to have had a lateral crest on each side bordering the abdomen, which is wanting in that and all other forms of the subclass Stegocephalia known to me. The lateral rod-plates of the abdominal armature look as though they were in life closely invested by the integument, or even projecting more or less from it. The forms of the abdominal rods and their alveoli are different from anything in the order known thus far.

Ceraterpeton tenuicorne Cope, *Report of the Geological Survey of Ohio,* "II. Paleontology," 1874, p. 372, Pl. XLII, Fig. 2 (by error on plate *C. recticorne*).

Pl. III, Fig. 2.

A partially preserved specimen of this species occurs in Mr. Lacoe's collection. It includes not only the head but the vertebral column as far as the caudal series exclusive, in bad preservation; part of the thoracic buckler and the greater part of the right hind leg and foot. As this species has been thus far known from a skull only, this specimen is very useful.

The slate is so split that the greater part of the surface of the skull is concealed in one of the slabs. On one of them, however, the presence of rows of fossæ is evident on the dentary and squamosal bones. The latter are convex outwards as in the type. The horns are placed wide apart and differ from those of the type in being a little incurved to the acute apex. The lateral pectoral shield exhibits a sculpture of radiating lines of small fossæ. There are small equal teeth on the premaxillary bone. The orbits are in the anterior half of the skull, and the nostrils and pineal foramen are distinct. The posterior foot is nearly equal in length to the leg, and the slender digits are four and probably five in number.

The accompanying measurements give a good idea of the proportions of this species.

Measurements.	MM.
Length of head to occiput, about	16
Greatest width of head	20
Length of horn from base	7
" " skull to line connecting posterior border of orbits	8
" " orbit	3
Interorbital width	3.5
Length of vertebral column to femur	33
" " femur	5.5
" " lower leg	3
" " second digit (not complete)	7
" " metatarsal of do	2
" " phalange i "	1.6
" " phalange ii "	1.5

This is the smallest species of the genus. It differs besides from the *C. punctolineatum* in the smoothness and acuteness of its horns, and in the weaker sculpture, where visible. It has the orbits more anterior and the horns shorter than in the still larger *C. divaricatum*.[1] The specimen shows that in this species, and probably in the others referred by me to this genus, both limbs are present; that the thoracic buckler and ribs are present, and that the spines of the vertebræ, though wide, are not sculptured. The digits are long and were probably connected by a natatory web. The block on which the specimen lies, contains several scales of fishes of the genus Cœlacanthus. From Cannelton, Pa., Mr. R. D. Lacoe.

SAUROPLEURA LATITHORAX, sp. nov. Pl. III, Fig. 4.

Represented by the anterior half of the animal, with the skull, on a block of coal shale from Linton, Ohio. The superior aspect of the ventral armature and of the thoracic shields is displayed, with the superior surface of the skull. The vertebral column is therefore wanting, but a number of ribs are preserved, as are also parts of both anterior limbs. Hind limbs wanting.

In the characters of its ventral armature, ribs and extremities, this species agrees with the type of the genus Sauropleura, *S. digitata* Cope. In the character of the skull, thoracic and ventral armature, and limbs it agrees with the genus Colosteus Cope. It is probable that the latter name must be regarded as a synonym of Sauropleura (as I have suggested in the paleontology of the *Geol. Survey of Ohio*, 1874, p. 406), although further material will be necessary to determine this point positively. In any case it may be assumed that Sauropleura had a thoracic armature from marks on the original specimen, and this is the only character in which it was supposed to differ from Colosteus, where it is present.

The ventral armature consists of longitudinal series of short scales, which series form chevrons directed forwards. The median scales are rounded in front on the superior side, viewed from above. The thoracic shields are rather wide for their length. The interclavicle (? præsternum) is rounded posteriorly, with a regularly oval outline, and the width is subequal for a distance anteriorly equal to the width. Each of the clavicles is as wide as the interclavicle posteriorly. The anterior extremities of all are concealed in the matrix, and the sculpture cannot be made out, as only the supe-

[1] Cope,

rior surface is visible. The interclavicle displays a low median longitudinal keel upwards.

The tympanic notch of the skull is feeble if present; it is quite possibly absent, as in the genus Acheloma. The muzzle is broadly rounded. The orbits are rather large, and the posterior borders fall a little behind the line which divides the length of the skull into two equal parts. The frontal is excluded from the supraorbital border by the large postfrontal. The postorbital is a longitudinal oval, acuminating to a point posteriorly. The cranial bones are honeycombed with fossæ, which are considerably wider than the diameter of the intervening ridges. The fossæ are generally elongate in a direction radial from the centre of the bone to which they belong. There is a long tooth near the extremity of the dentary bone. Most of the remaining teeth are concealed, but some very small ones on the premaxillary and maxillary bones are visible, and parts of some larger maxillary teeth appear below the posterior part of the orbit. The bases of the teeth are coarsely incised grooved, *i. e.*, the surface is inflected.

The legs are robust and the digits rather slender. The only ungual phalange preserved is slender, acute, and slightly curved, like that of many lizards. The humerus is robust and considerably expanded at the extremities. The ulna and radius are of usual proportions, and about three-fifths the length of the humerus. The metacarpals and phalanges are slender. No osseous carpus. Four digits are preserved; whether there is another cannot be ascertained. The ribs are long, rather slender, and not alate.

Measurements.	MM.
Length of skull to occipital condyles	46
" " " " " table, posterior border	35
Width " " at angles of mandible	86
Length " " from posterior border to orbit (axial)	26
" " orbit	15
Width " "	11
" " interorbital space	17
Length " long mandibular tooth	6
Width " interclavicle above	23
" " clavicle above (greatest)	19
Five abdominal scales in oblique line	10
Length of humerus	20

Measurements.				MM.
Length of ulna				11
"	" first finger, total			15.5
"	"	"	metacarpal	6.5
"	"	"	phalange i	5
"	"	"	claw	4

The inequality of the lengths of the teeth with long ones anteriorly and medially, is what is seen in the type of Colosteus, *C. scutellatus* Newb., and in Anisodexis Cope. The lower jaw of the species from Linton which I called *A. enchodus* is not longer than that of the present species, if as long; but it is much more robust, and the elongate teeth are much longer, relatively and absolutely. It may belong to the same genus. As compared with the *Sauropleura* (*Colosteus*) *scutellata*, this species differs in having a median V-shaped series of abdominal scales, and in the more slender digits. From the two other species referred to Colosteus, on the strength of thoracic scuta, this species differs, in the rounded posterior outline. In those species (*C. foveatus* and *C. pauciradiatus*) the posterior borders are sharply convergent to an obtuse angle. As compared with *Sauropleura digitata* Cope, this species has relatively a much shorter forearm. In that species the ulna is five-sixths the length of the humerus, and the digits are less slender than in the *S. latithorax*.

From the collection of Mr. R. D. Lacoe, to whom I owe the opportunity of studying the unique specimen.

REPTILIA.

Isodectes punctulatus Cope, *American Naturalist*, 1896, p. 303. *Tuditanus punctulatus*, *Trans. Amer. Philos. Soc.*, 1874; *Geol. Survey of Ohio*, ii, 1874, p. 392, Pl. xxxiv, Fig. 1 (*Tuditanus longipes* in explanation, by error).

Pl. III, Fig. 3.

A collection from Linton, Jefferson county, Ohio, obtained from Mr. Samuel Houston, contains the greater part of the skeleton of what I suppose is this species. The head, scapular arch and one fore limb are lost. The remainder agrees very well with the typical specimen which was obtained by Dr. Newberry from the same locality and horizon.

There are eighteen dorsal and twenty-three caudal vertebræ, and parts or wholes of twenty-two dorsal and three caudal ribs, preserved. The vertebral bodies are amphiplatyan or amphicœlous, but which, is not readily determined. Where the centra are split, an indication of notochordal canal is visible, but the impression may be that of the external right face of the centrum, and not that of the cast of that canal. Most of the centra expose the left side, displaying low and contracted neural spines on the lumbar region, and none on the dorsal. There are two sizes of caudal centra, a longer and a shorter. Where these occur in pairs they might be supposed to be the halves of a divided centrum, such as occur in the Lacertilia, but several of them are single, and in place. No trace of chevrons is to be seen. The ribs are slender, not alate, and recurved. The caudal ribs are shorter and more strongly recurved. The sacrum and pelvis are too much obscured for description.

The posterior limbs and feet are the most interesting part of this specimen. The femur is moderate, with expanded extremities, the distal divided by a popliteal groove. The tibia has the usual triangular head and contracted distal end, and has a straight shaft. The fibula is slightly curved, the interosseous border being strongly concave, and the distal end is oblique, and is wider than the proximal. The tarsus includes but two elements in the proximal series, of which the internal (intermedium all or in part) articulates with both tibia and fibula. The fibulare is a little the larger, and has a longer distal articular border. Distad of these there are six elements, one opposite each metatarsal, except the fifth, which has two. If we call the internal No. 1, and the external No. 6, they are arranged in the order of size as follows, beginning with the smallest, 6–3–1–5–2–4. No. 1 is considerably proximad of the others, as is the case with some existing salamanders. No. 3 is separated from contact with the proximal elements, by the large No. 2, which thus has the position of *centrale carpi*, but which gives attachment to the second metacarpal. The subdiscoid No. 4 articulates with both astragalus and calcaneum, but most extensively with the calcaneum. This tarsus is quite regular, and every bone is in place. That of the opposite side is turned over on the leg, and the astragalus is missing.

The posterior digits are long and slender, and of various lengths, although the metatarsals are of subequal length. The first and fifth digits are the only ones with all the phalanges preserved. These number two and four respectively, with a possible doubt as to the first digit. The other toes are represented by the following numbers of phalanges: second, 3; third, 3; fourth, 5. Enough remains of the manus to show that there were at least four digits, composed of segments rather shorter than those of the pes. Three carpals remain, perhaps centrale, and c. i and ii; c. i is proximad to c. ii, and on the inner side of the centrale.

As a result it appears that the tarsus is very different from that of the Pelycosauria. How nearly it approximates the other Cotylosauria it will be my object to show shortly. It is primitive and only lacks identity with the batrachian tarsus in the absence or fusion of the tibiale.

Measurements.	MM.
Length of specimen	128
Expanse of ribs	18
Length of rib, on curve	14
" " centrum of fifth vertebra anterior to sacrum	4
Depth " do, with arch	4
Length " femur	15
Distal width of do	4
Length of tibia	7
Width " head of do	3
" " distal end of fibula	3.5
" " tarsus	6
Length " metatarsal iv	4.5
" " phalange i of digit iv	4
" " " ii " "	3.5
" " " iii " "	3.5
" " digit v, with metatarsal	16
" " median caudal vertebra	3

This specimen is of importance as pertaining to the oldest known reptile, and the only one which has been thus far positively identified from the Coal Measures. I announced this identification in the *American Naturalist*, 1896, p. 303.

EXPLANATION OF PLATES.

Plate I.

Scales of Sagenodus from the Coal Measures of Mazon Creek, Illinois, natural size.

Fig. 1. *S. foliatus* Cope type; 2–3. *S. reticulatus* Newb.; 4. *S. conchiolepis* Cope type; 5. *S. lacovianus* Cope type; 6. *S. quincunciatus* Cope type; 7. *S. browniæ* Cope type; 8. *S. magister* Cope type; 9. *S. gurleianus* Cope type.

Plate II.

Figs. 1–3. Scales of Holoptychius, nat. size, except Fig. 2×2.

Fig. 1. *H. serrulatus* Cope type; 2. *H. latus* Cope type; 3. *H. flabellatus* Cope type.

Fig. 4. *Sauropleura latithorax* Cope type, natural size.

Plate III.

Fig. 1. *Ctenerpeton foveolatum* Cope, from below, natural size; 2. *Ceraterpeton tenuicorne* Cope, from above, natural size; 3. *Isodectes punctulatus* Cope, natural size.

[The Secretaries deem it proper to state that when the proofs of the plates of this paper were taken to Prof. Cope he was too ill to examine them, and owing to his subsequent death they have been compelled to print the plates as drawn, without the benefit of his correction.]

Stated Meeting, February 5, 1897.

Vice-President, Dr. PEPPER, in the Chair.

Present, twenty-five members.

A letter was received from Prof. Goldwin Smith, resigning membership in the Society. The resignation was accepted.

The Standing Committees for the coming year, as appointed by the President, under resolution of the Society, were then announced as follows:

Finance.—William P. Tatham, William V. McKean, Philip C. Garrett.

Hall.—J. Sergeant Price, William A. Ingham, Joseph M. Wilson.

Publication.—Daniel G. Brinton, George H. Horn, Persifor Frazer, I. Minis Hays, Frederick Prime.

Library.—Edwin J. Houston, Frederick Prime, William H. Greene, Albert H. Smyth, Thomas Hewson Bache.

Michaux Legacy.—Thomas Meehan, William M. Tilghman, Angelo Heilprin, William Powell Wilson, Arthur E. Brown.

Henry M. Phillips Prize Essay Fund.—William V. McKean, Craig Biddle, Joseph C. Fraley, C. Stuart Patterson, Mayer Sulzberger, the President, the Treasurer.

Programme.—William Pepper, Persifor Frazer, William A. Ingham, Joseph C. Fraley, I. Minis Hays.

The death was announced of Horatio Hale, of Clinton, Ont., December 29, 1896.

Prof. E. D. Cope presented a paper on "New Paleozoic Vertebrata from Illinois, Ohio and Pennsylvania," which was read by title.

The following papers constitute the discussion prepared for this meeting by those invited to present the various aspects of the subject selected, viz., "The Origin and Chemical Composition of Petroleum."

Prof. Sadtler read a paper on "The Genesis and Chemical Relations of Petroleum and Natural Gas."

Prof. Peckham, of Ann Arbor, read a paper on "The Nature and Origin of Petroleum."

A communication from Mr. David T. Day was read, entitled "A Suggestion as to the Origin of Pennsylvania Petroleum."

The Secretary read by title two papers by Prof. Phillips on "The Genesis of Natural Gas and Petroleum," and on "The Occurrence of Petroleum in the Cavities of Fossils."

Prof. Mabery then presented his views on the composition of Petroleum.

Remarks in discussion were then made by Dr. Sadtler, Mr. Wharton, Prof. Mabery and Prof. Peckham, and Prof. Mabery closed the discussion with a warm recognition of Dr. Sadtler's and Prof. Peckham's work.

THE GENESIS AND CHEMICAL RELATIONS OF PETROLEUM AND NATURAL GAS.

BY SAMUEL P. SADTLER, PH.D.

(*Read February 5, 1897.*)

Of natural products in the mineral kingdom, few have excited the interest of geologists and chemists in the same degree as what in the broad sense we call bitumen. Occurring as it does in solid, liquid and gaseous condition in almost all parts of the world, and in amount varying from the slight bituminous impregnation of shales, limestones, sandstones, and other rocks to the great petroleum deposits which are now worked in this country and Russia, it has furnished ever-new and interesting material for scientific study and discussion.

This widespread occurrence and the varied forms under which it is brought to our attention would be quite sufficient to explain its interest from a geological point of view, but when we add to this that in its main forms of production, petroleum and natural gas, chemists find represented those simplest forms of organic compounds, the hydrocarbons, we have an additional element of interest.

Under these circumstances, it would be hard for the scientific student to refrain from theorizing as to the origin and conditions of formation and storage in nature of this great class of products. And if these theories already possessed interest in the earlier half of this century, might we not suppose that the great economic value which petroleum and natural gas have attained in the last few decades would add greatly to this? The question has indeed become a very large one, and the mass of literature pertaining thereto has already become so great that it would be impossible in the brief limit of time assigned me to cover it even in outline. Leaving therefore the broad subject of natural bitumens, it has been thought well to take for such discussion, as time allows, the narrower question of "the origin and chemical character of petroleum." And as the Society is honored this evening by the presence of several gentlemen who are known by contributions already made to this question, and have consented to favor us with papers specially prepared for this occasion, I shall merely state in brief outline the several well-known theories that have been advanced from time to time, and add an account of some experimental results that I have myself obtained which I think will have a bearing upon some of the views now held.

The theories as to the origin of petroleum may be divided broadly into those which attribute it to Inorganic Sources and those which consider it to be derived from Organic Sources. Under the first of these heads, we may again distinguish between the theories which consider it merely as a natural emanation and those which attribute it to the result of definite chemical reactions.

The first suggestion of the emanation theory for the origin of petroleum seems to have come from Alexander von Humboldt, who in 1804, in describing the petroleum springs in the Bay of Cumaux on the Venezuelan coast, throws out the suggestion that "the petroleum is the product of a distillation from great depths and issues from the primitive rocks, beneath which the forces of all volcanic action lie." Rozet (1835), Prott (1846), Parran (1854), and Thoré (1872), in writing upon the asphalt and petroleum occurrences in France, all seemed inclined to connect these formations with volcanic, or at least igneous and eruptive, agencies.

Somewhat similar was the theory advanced by the French geologist Coquand, who, because of the association of mud volcanoes with the occurrence of petroleum in Sicily, the Apennines, the peninsula of Taman and the plains of Roumania, concluded that mud volcanoes produced petroleum and other forms of bitumen by converting marsh-gas into more condensed hydrocarbons. This derivation of liquid and even solid bitumens like ozokerite from marsh-gas as an original source was also advanced as a theory by Grabowski, who has made special studies on Galician ozokerite.

The simplest of the emanation theories, however, is that of the Russian geologist Sokoloff, who believes that petroleum is a cosmic product, formed in the crust of the earth as bitumens are formed in meteorites and comets by direct union of the elements hydrogen and carbon. According to this theory, the liquid and solid bitumens represent successive stages in the condensation and oxidation of simpler gaseous hydrocarbons.

These emanation hypotheses do not find much acceptance at present. The connection between the petroleum occurrence and volcanic activity or hot springs seems to be far from general, and may indeed be classed as local and fortuitous; the oil does not issue from the earth at any higher temperature than that of the surface, as it might be expected to if connected with deep-seated volcanic or cosmic activity; and lastly, the most abundant oil deposits are not located in the regions where upheaval and fracture of the earth's crust show most strongly.

More interest perhaps has been awakened by the theories of inorganic origin which involve definite chemical reactions. Foremost among these was that of Berthelot, who, in 1866, advanced the theory that the interior of the earth contained free alkali metals, and that these, when acted upon by carbonic acid or an earthy carbonate at high temperatures, would form acetylides or carbides of the alkali metals which decompose with water to form hydrocarbons analogous to those found in petroleum. If, then, water containing carbonic acid gas were to reach these metallic masses by infiltration and act upon them at high heat and under pressure, both liquid and gaseous hydrocarbons would result. The production of metallic carbides as a product of the electric furnace, and their ready decomposition for the production of acetylene gas, now carried out on a commercial scale, has added new interest to this theory of Berthelot's.

This line of hypothesis was farther developed by Byasson in 1871, who obtained petroleum-like products by the action of steam and carbonic acid gas upon iron and its sulphide at a high temperature. Cloez, in 1877, also obtained petroleum-like hydrocarbons by the action of dilute acids, and even of boiling water, upon the carbides of iron such as exist in spiegeleisen. In the paper of the Russian chemist Mendelejeff, however, published also in 1877, this theory is most fully elaborated. The existence of metallic carbides in the depths of the earth he considers likely from the fact that similar carbides are found in meteorites, and that metallic iron may occur in large deposits in the interior of the earth he considers possible, because the mean specific gravity of the earth, 5.5, is notably higher than that of ordinary rock material. If, then, water be supposed to have infiltrated through fissures in the earth's crust, we have the conditions shown by experiment as capable of yielding petroleum-like hydrocarbons. The same steam which, acting upon the metal or metallic carbide, was capable of forming the petroleum, could also force its vapors when formed through the fissures until on cooling they condensed and were absorbed in strata capable of holding them in liquid form. The eminent geologist Abich, who had made a study of the Caucasian oil field, also joined in the acceptance of this theory of Mendelejeff, and it may be said to be the one of the inorganic theories that has found the most general indorsement.

The great preponderance of belief is, however, at the present time against this or any other theory based upon purely inorganic materials or reactions. The entire absence of petroleum from the archaic formations, from which traces of fossil life are also absent, and the occurrence of the petroleum in sedimentary formations which have been free from any volcanic or metamorphic disturbance, go to render these emanation theories improbable. The fact, moreover, that while the hydrocarbons of petroleum show a range of temperature of condensation from 0° to 300°, which would necessarily distribute them in different strata if they rose from the interior in vapor form, we find them all, from the highest to the lowest, admixed in one and the same oil-bearing formation, also speaks against the probability of the theories stated above.

Turning now to the theories of the organic origin of petroleum, we note first the belief that it comes essentially from vegetable sources. Thus Prof. Lesquereux considered that the Pennsylvania oil was formed from the remains of marine algæ, because the Devonian shales which accompany the oil formation contain an abundance of fossil fucoids. It is pointed out, however, by Höfer and other critics of this theory that in many localities fucoid remains are abundant without a trace of bituminous products accompanying them.

E. W. Binney having observed petroleum oozing from a decomposing bed of peat in England, which had been covered in with sand, considered that it came from a decomposition of the peat out of access of air. However, it has been pointed out that this was an isolated observation, and that in many other peat bogs similarly covered no evidence of petroleum has been found.

Wall and Kruger, after studying the asphalt occurrence in the island of Trinidad, proposed the theory that asphalt and petroleum were formed by the decomposition of woody fibre, of which they found abundant traces in the asphalt deposits. A later observer, Rupert Jones, however, on extracting Trinidad asphalt with hot turpentine found animal remains so clearly that a derivation from these is at least as probable.

We may mention also the earlier views of Reichenbach, who viewed petroleum as formed by a destructive distillation of vegetable remains simultaneously with the formation of the coal deposits, but in answer to this it is only necessary to note that the petroleum and the coal do not occur together in the majority of instances and that petroleum differs essentially in chemical composition from either wood-tar or coal-tar as ordinarily obtained.

The eminent French geologist, Daubrée, also found a vegetable origin for petroleum. He says that "it appears not to be a simple product of dry distillation, but to have been formed with the concurrent action of water and perhaps under pressure." He adduces in support of his view the fact that by the action of superheated steam upon wood he had obtained both liquid and gaseous products analogous to petroleum.

The belief in the animal origin of petroleum has had advocates equally as positive and persistent. In this country, J. D. Whitney, the former State Geologist of California, and T. Sterry Hunt, who was well acquainted with both the Canadian and Pennsylvania oil fields, were its chief advocates. The latter has produced many strong illustrations in his study of Canadian formations of his view that fossiliferous limestones, the remains in which are mainly if not exclusively of animal origin, were the original beds in which the petroleum was formed.

In Europe, the most prominent advocates of the animal origin of petroleum have been Höfer and Engler. The former of these writers in his work, *Das Erdoel und seine Verwandten*, published in 1888, summarizes the arguments for believing petroleum to be of animal origin as follows:

1. We find petroleum in original deposits with animal remains, but not or with only the smallest traces of vegetable remains, as for example in the fish shales of Carpathia and the limestones of Canada studied by T. Sterry Hunt.

2. Shales which, on account of their high per cent. of bitumen, are adapted for the production of oil or paraffine, are also rich in animal and poor or entirely void of vegetable remains, as for example the bituminous shales of the Lias formation in Swabia and Steierdorf (Banat). The copper-bearing shales of Mansfield, which contain as high as twenty-two per cent. of bituminous matter, also carry an abundance of animal remains, but only very rarely any vegetable remains.

3. Rocks which are rich in vegetable remains as a rule are not bituminous, but they become so if animal remains accompany the other.

4. By the decomposition of animal remains it is possible to form hydrocarbons analogous to those of petroleum oils.

5. O. Fraas observed petroleum oozing from a coral bank on the borders of the Red Sea, where it could only have had an animal origin.

The fact that origin from animal remains makes it necessary to account for the nitrogen, is met by the fact that most asphalts and bitumens, including petroleum, do contain nitrogen. That they do not contain more is explained, according to Höfer, by the circumstance that the nitrogen is lost in volatile compounds like ammonia. Of course animal remains are found in many formations that do not contain bitumen or petroleum, but the conditions may have been unfavorable for its accumulation and retention in these cases. The actual formation of petroleum-like compounds from animal products had been carried out experimentally some years before Höfer's publication, by our countrymen, Warren and Storer, who distilled the lime soap of menhaden (fish) oil, and obtained members of the methane, ethylene and benzene series of hydrocarbons, such as are found in petroleum.

However, Höfer's theory was taken up as the suggestion for experimental study by Engler, of Carlsruhe, and at his hands it has received a more definite statement. Engler distilled 490 kilos. of menhaden oil at a temperature beginning at 320° C. under a pressure of ten atmospheres, and increasing to 400° under a pressure of four atmospheres. He obtained about sixty per cent. of an oil distillate of 0.815 specific gravity. Thirty-seven per cent. of the distillate was taken out by shaking with sulphuric acid, indicating unsaturated hydrocarbons, while the remainder yielded, on fractional distillation, pentane, hexane, normal and secondary hexane, normal octane and nonane. A burning oil fraction was separated, and in his latest experiments solid paraffine was also obtained from the heavier portions. Prof. Engler gave a *resumé* of his experimental results at the World's Fair Congress of Chemists, in Chicago, in August, 1893, and I had the pleasure of hearing it and examining his specimens at that time. In consequence of this work of Engler, which he extended later to lard oil as well as to menhaden oil, and to artificial tri-oleines as well, the belief in the animal origin of petroleum has become quite the prevalent one.

Let us, however, take up for a moment the idea of the joint animal and vegetable source. This joint origin was advocated first of all by Prof. J. P. Lesley, the Director of the Second Geological Survey of Pennsylvania, and an honored Vice-President of this Society. He believes that "it is in some way connected with the vastly abundant accumulations of Paleozoic sea weeds, the marks of which are so infinitely numerous in the rocks, and with the infinitude of coralloid sea animals, the skeletons of which make up a large part of the limestone formations which lie several thousand feet beneath the Venango oil-sand group." The same view was held by the late C. A. Ashburner, of the Pennsylvania Geological Survey.

Prof. Edward Orton, of the Ohio Survey, summarizes his views in the following postulates: (1) Petroleum is derived from organic matter; (2) Petroleum of the Pennsylvania type is derived from the organic matter of the bituminous shales and is probably of vegetable origin; (3) Petroleum of the Canada type is derived from limestones and is probably of animal origin.

Prof. Peckham, in his report on Petroleum for the Census of 1880, also makes a distinction in the origin of different classes of petroleums. He divides all bitumens into four classes:

1. Those bitumens that form asphaltum and do not contain paraffine.

2. Those bitumens that do not form asphaltum and contain paraffine.

3. Those bitumens that form asphaltum and contain paraffine.

4. Solid bitumens that were originally solid when cold or at ordinary temperatures.

"The first class includes the bitumens of California and Texas, doubtless indigenous in the shales from which they issue. The exceedingly unstable character of these petroleums, considered in connection with the amount of nitrogen that they contain and the vast accumulation of animal remains in the strata from which they issue, together with the fact that the fresh oil soon becomes filled with the larvæ of insects to such an extent that pools of petroleum become pools of maggots, all lend support to the theory that the oils are of animal origin.

"The second class of petroleums include those of New York, Pennsylvania, Ohio and West Virginia. These oils are undoubtedly distillates and of vegetable origin. The proof of the statement seems overwhelming."

Leaving the question of origin for the present with this rapid survey of the views of the more prominent writers on the subject, and reserving for the end of this paper the mention of some few experimental results of my own which bear on it, I will briefly allude to the other question of the conditions of formation of the bitumen or petroleum. Here of course we practically leave the theories of inorganic origin to one side and assume that its source is organic. Was it formed where it is now found *in situ* or is it a distillate from lower-lying formations?

As already stated, Sterry Hunt believed that the fossiliferous limestones were the source of the Canadian oil, and he also strenuously insisted that they were formed in this same formation and did not come into it from an outside source. This view of the production of the petroleum *in situ* is also in the main supported by Profs. Lesley and Orton, although both seem to admit that under some circumstances a modified distillation takes place. The latter says: "Different fields have different sources. We can accept without inconsistency the adventitious origin of the oil in Pennsylvania sandstones and its indigenous origin in the shales of California or in the limestones of Canada, Kentucky or Ohio." On the other hand, Profs. Newberry and Peckham have advocated the theory that the oils of New York, Pennsylvania, West Virginia and Ohio at least were products of a slow fractional distillation. Prof. Newberry speaks of black Devonian shales as the source of supply in this process, while Prof. Peckham takes in both beds of shale and limestone containing fucoids and animal remains as subjected to the distillation process.

In concluding, I have a small contribution to offer to the experimental data which bear upon the question of possible origin, and upon which we can theorize as to conditions of formation.

Engler, as already mentioned, distilled menhaden oil under pressure, and afterwards extended his experiments to lard oil and artificial oleins. From his results he is led to believe in the exclusively animal origin of petroleum. I have found that linseed oil, and presumably the other vegetable seed oils, may be made to yield similar products, and have even obtained solid paraffine from this source. While it has long been known that inflammable vapors are given off when linseed oil is boiled for varnish making and similar purposes, very little attempt has been made to collect and study the composition of these vapors. Schædler, in his exhaustive work on the vegetable and animal oils, simply makes the statement that small quantities of hydrocarbons are present in the vapors resulting from this destructive distillation.

Finding that in one case that came under my attention linseed oil was being boiled for varnish making under pressure, and that considerable quantities of a liquid distillate were being condensed in the dome of the large still and returned to the body of the oil, I arranged for the collection of these condensed vapors and collected them for examination.

At first the odor of acrolein was very pronounced and powerful, showing that the glycerine of the glycerides composing the oil was being decomposed; later the odor was more that of a cracked petroleum oil, showing that the linoleic and other acids of the oil were undergoing decomposition. The raw distillate collected after this acrolein odor had nearly disappeared, I found had a specific gravity of 0.860 and had changed so thoroughly from the original linseed oil that it showed a saponification equivalent of only 1.09, indicating that it was mainly a neutral oil and presumably made up largely of hydrocarbons. I might say here that I examined the linseed oil which was used in this test. It was a clear "old process" oil, of specific gravity 0.929, and showed a saponification equivalent of 183, which is normal for linseed oil.

The distillate above referred to was then redistilled from a small iron retort and two fractions collected, leaving a residue in the retort which had the appearance and odor of a reduced petroleum oil or residuum, such as is used in the manufacture of vaseline and similar products.

The two fractions were found to resemble what are known as paraffine oils in considerable degree, showing the characteristic fluorescence of these. They were given a partial treatment with sulphuric acid and the results are shown. From a portion of one of these fractions, on chilling in a freezing mixture, scale paraffine was also separated, of which a sample is shown. Of course the fractions must be obtained on a sufficiently large scale to admit of thorough purifying before the character of the hydrocarbons can be studied. At present they contain impurities such as aldehyde-like and possibly ketone products. They reduce ammoniacal silver solutions and indicate thus the presence of these impurities.

These results, which of course are only preliminary, are sufficient to show that we have hydrocarbon oils analogous to the natural petroleum or mineral oils formed when linseed oil is distilled under pressure. It is difficult then to see how we can avoid widening Engler's theory so as to include the vegetable seed oils as probable additional sources of petroleum. Moreover, I see no reason, if lard oil will yield the results which Engler has obtained, to doubt that vegetable oleins like olive oil and its class may also be found to be capable of the same changes.

We are thus brought from an experimental point of view to come to the acceptance of the theory of the joint animal and vegetable origin of petroleum that the majority of geologists have settled upon as according best with their study of its local occurrence.

ON THE NATURE AND ORIGIN OF PETROLEUM.

BY S. F. PECKHAM.

(*Read February 5, 1897.*)

Concerning the nature and origin of petroleum, I think we may say, after forty years of study and discussion, that we have not yet learned its alphabet with certainty. As petroleum is one of the forms of bitumen, in the line from natural gas to asphaltum, I do not think it has an origin independently of the other forms, and I shall therefore discuss the origin of bitumens together, as including petroleum.

Since I indulged my "Retrospect,"[1] two years ago last summer, two works have appeared which notably discuss the origin of bitumens, and I have in the course of my investigation of asphaltums and California petroleum, during the same period, noted a number of facts that bear upon the solution of this problem. In closing the "Retrospect" that I wrote while in southern California, and which was in part a reply to criticisms made by our friend, Prof. Orton, I remarked that I did not consider it necessary to represent in terms of Fahrenheit's thermometer the temperature at which any given specimen of petroleum was produced nor to produce the coke that resulted from the distillation. On reading over the paper since it appeared in print, I have feared that perhaps it had impressed some readers as dogmatic or as begging the question. It is sometimes difficult to express deep convictions with enthusiasm and not at the same time appear dogmatic. The Devonian shales, where they outcrop at Erie, Pa., have not apparently been subjected to alteration; yet, a number of wells drilled into them, have yielded an oil somewhat dense and of a bright green color. I believe that that oil was a product of distillation at a low temperature and under comparatively little pressure, the heat required being generated spontaneously within the shales. In Ventura county, southern California, metamorphism, that has resulted from some sort of action that has generated heat, has left masses of originally highly bituminous shale not only void of volatile matter but void of carbon as well. The expulsion of carbon is complete. The temperature must have been adequate, be the source of heat whatever

[1] *Am. Jour. Science* (3), xlviii, 389; Nov., 1894.

it may, yet there is no coke and no evidence that the temperature approached that of a brick kiln, nor such a temperature as in the ordinary processes of technology is found necessary to produce similar changes within periods of time upon which such processes are contingent. It was in the midst of such phenomena as I have just described and in the light of these facts that I then asserted that we cannot "reason from the processes of technology, bounded as they are by time and space, to the infinity of nature which it is impossible to imitate;" meaning that such reasoning cannot be applied to details.

A book was published in 1895, of which the eminent Swiss geologist, M. August Jaccard, was the author. The fact that it was a posthumous work leads one to pass lightly over mere blemishes of manner and style, and to note only those errors of judgment which led the author to erroneous conclusions. The book manifests a wide range of reading within the limits of publications in the French language, which has made it necessary that the author should confine himself to translations of the many memoirs that have appeared by English and American authors, and while the notices of such authors are frequently inadequate, few, if any, are omitted. M. Jaccard passes in review all of the different theories that have been proposed as a possible explanation of the phenomena observed in relation to the occurrence of bitumens in the Upper Valley of the Rhone, and discards all of those that regard bitumen as resulting from any cause or causes other than the alteration of animal remains by a special process of bituminization that has converted the organic matter directly into bitumen. He says, "distillation is an hypothesis absolutely destitute of proof" (p. 110), and, referring to the views of MM. Daubrâe, Lartet and Coquand, he says further that "Their error consists in the fact of having confounded the formation of bitumen with the phenomena of its appearance (*reapparition*) at the surface which is posterior to it."

M. Jaccard then proceeds to set forth a system of nomenclature of his own and says, "It is in vain to wish to attempt a rational and systematic classification of natural hydrocarbons, solid and liquid and gaseous. It is in vain to set forth the multiplicity of names that have been applied to them by different authors. The expressions naphtha, petroleum, maltha, glutinous, viscous or solid bitumen, asphalt or pisasphalt, etc., are employed concurrently and without determined reasons. Their state, whether solid, liquid or gaseous, often depends upon the temperature at which they are at the moment when they are observed. . . . . Petroleum becomes solid when it has lost its light oils by exposure. They designate as asphalte a calcareous rock impregnated with bitumen, whilst if it be mixed with sand or gravel they apply the term petroleum" (p. 113).

"In presence of this uncertainty, it has appeared to me preferable to proceed to the study of the deposits by groups, and to adopt thus a purely methodical system.

"To this end I have established the four following groups:

"1. The asphaltic and bituminous deposits.

"2. The bituminous schists.

"3. The petroliferous and bituminous deposits.

"4. The natural combustible gas."

He then proceeds to discuss the subject along these inadequate and purely artificial lines, which time will not permit me to analyze in detail. It is sufficient for my purpose to say, that he concludes that bitumens have been produced in every case by a special decomposition of animal matter at the points where they are now found.

He thinks that because the bituminous limestones of Seyssel and Val de Travers are intercalated between beds of barren rock that the bitumen must have been formed *in situ*. That is by no means a necessary conclusion. The bitumen in a state of vapor, and probably accompanied by steam, expanded into the porous beds laterally, while passing through fissures in the compact and barren beds. When the Seyssel rock has been exhausted of its bitumen by chloroform and is examined under a microscope, it is found to be an amorphous mass of coarse-grained chalk with the finest particles one ten thousandth to one twenty thousandth of an inch in thickness—so fine that they pass through fine filter paper.

Any one familiar with the sea-shore has found shells of the common clam (*cardium*) filled with sand and saturated with the products of the decomposition of the soft parts of the bivalve dissolved in water. It is not an infrequent occurrence in regions where bitumen is abundant upon sea-coasts to find the shells of such bivalves filled with sand saturated with bitumen. The carbon contained in the solid or semi-solid bitumen required to saturate the dry sand that fills such shells is many times that found in the dried soft parts of the animal that occupied the shell. Such shells are common on and near the coasts of southern California. M. Jaccard calls attention to such shells as occurring in various places, but especially in the Val de Travers and its neighborhood, and seems to think they offer convincing proof that the bitumen originated where it is now found. Such an argument would never occur to one familiar with the sea-shore. The shells are first filled with sand and then saturated with bitumen, which enters them either as a liquid or hot vapor. I have seen multitudes of shells filled with bitumen and mixed with sand, fragments of shells, dirt, and crystallized carbonate of lime, none of which are a part of the animal that occupied the shell.

The second work to which I refer is the late monumental publication by Boverton Redwood, on Petroleum. After the most complete and wholly fair as well as the latest *resumé* of all the theories that have been advanced by the writers of both Europe and America, he sums up as follows:

"From the account given in this section, it will be seen that there has been an abundance of speculation as to the origin of bitumen and that, in regard to some of the theories, a considerable amount of experimental proof has been forthcoming. Probably, on the whole, the Höfer-Engler views at present have the largest number of adherents, and in respect, at any rate, to certain descriptions of petroleum, are the most worthy of acceptance. At the same time, a careful study of the subject leads to the conclusion that some petroleum is of vegetable origin, and it therefore follows that no theory is applicable in all cases."

Engler, like Warren, distilled fish oil and obtained petroleum-like products. He then distilled dried fish and other animal remains, and obtained altogether different products.

"Dr. Engler therefore considers that some change in the animal remains must have taken place in the earth, whereby all nitrogenous and other matters, save fats, were removed, the petroleum being formed from this fat alone, by the combined action of pressure and heat or by pressure only.

"In summing up the evidence as to origin, Höfer expresses the belief that petroleum is of animal origin, and has been formed without the action of excessive heat, and observes that it is found in all strata in which animal remains had been discovered."

Combining these two statements, we arrive at this conclusion as the Höfer-Engler theory, that bitumens are of animal origin, formed at low temperatures from fats alone by the combined action of pressure and heat.

Steam is left out of this formula and it is therefore inadequate. There is no evidence whatever that any portion of the crust of the earth has ever been subjected to the combined action of heat and pressure without the presence of steam or hot water, and in my judgment the steam has been a very potent factor in determining not only the formation but the transference of bitumens.

I have been many times told that the Turrellite of Texas consists of a mass of loose shells cemented together with bitumen. As it had that appearance, I never questioned the statement, until lately I had occasion to examine a specimen of this mineral. I pulverized some of it and proceeded to analyze it by solvents. I found that a portion of the mineral matter passed through fine filter paper. I then digested a piece of it in successive portions of chloroform, until the chloroform was no longer colored. There remained a white shell-rock, or coquina, quite firm and strong, very light in weight, with the cavities of some of the shells partly filled with crystallized rhomb-spar; together with fragments of shells and dust. Under the microscope some of the dust was only one twenty thousandth of an inch in thickness. The shells had been subjected to the action of hot water after all traces of the soft parts of the animals had disappeared and a part of the lime had been dissolved and redeposited in the cavities of the shells and between them, thus cementing them together; and this anterior to the entrance of the bitumen, which must have filled the shell-limestone as a vapor or in a fluid or semi-fluid condition. When separated from the shells the bitumen is very pure and uniform in its composition, containing many times the amount of carbon that existed in the soft parts of the animals that made the shells their home. The porous shell-rock simply afforded an adequate receptacle for the bitumen that was distilled or sublimed into it.

I have lately examined California petroleums more closely than I ever had before. I have distilled off the lightest portion from some Wheeler's Cañon green oil that I took from the Cañon in 1866. I also distilled about fifty per cent.—the lightest portion—from some Pico Cañon oil that I got from there two years ago. While in California in the fall of 1894, I distilled from several samples of black oil, taken from wells in the Sespè and Torrey Cañons and near Bardsdale, about twenty-three per cent. of the lightest portion. The distillation was conducted in a common tubulated glass retort with a thermometer introduced into the tubulure in such a manner as to indicate the temperature at which the condensing vapor passed over. This was the first time I had ever distilled these oils in such an apparatus, and some of the results observed were exceedingly interesting. The crude oils contained a little water, as all petroleums do, which came over with the light distillate, at or below 100° C. As the boiling point of the oil and the temperature of the condensing vapor arose, at 120°–140° C., water again appeared. The two portions of water distilled over at temperatures separated by at least 30° C. The last portion appeared, in part, as an emulsion that collected in white drops upon the neck of the retort, and, gathering, ran through the condenser to the receiver, where it fell through the column of oil and collected as water at the bottom of the receiver. On standing twelve hours, small spots and patches in the neck of the retort appeared of a purple color, and a deposit that resembled argol appeared as a precipitate in small quantity at the point of contact between the oil and water in the receiver. While an appreciable amount of this precipitate appeared in the distillate from the black oil, only a trace was present in the distillates from the oils from the Pico and Wheeler's Cañons. With sulphuric acid, followed by sodium hydrate, this precipitate gave a qualitative reaction for one of the esters of the pyridin bases; that is to say, dilute sulphuric acid dissolved a part of it, leaving a purple residue, and from the sulphuric acid solution sodium hydrate precipitated white flakes having the odor of pyridin. The distillates also gave the usual reaction for these esters in small quantities. Fractionated in a bulb apparatus with beads, the distillate from black oil has yielded "heaps" corresponding to the boiling points of the benzoles and naphthenes. This work is still incomplete.

The facts of greatest interest, however, in reference to these oils, that this latest work has demonstrated, relates to their sulphur content. An observation that I made many years ago has been often quoted, that in one instance I distilled a California oil that contained so much sulphur that the sulphur condensed in the neck of the retort. As I remember the experiment, the amount of oil distilled was about half a litre; and a button of pure sulphur condensed in the neck of the retort at least half a centimeter in diameter. This oil was from the Cañada Larga spring, which issues from strata containing a large amount of free sulphur. I have never seen another California oil from which this experiment could be repeated; and I have long since concluded that the sulphur was in this instance dissolved in the oil.

While in California a few years ago, I was engaged in distilling these petroleums in quantities ranging from a few gallons to thousands of barrels. I looked in vain for any evidence that they were sulphur petroleums. It was only after I had begun fractioning the light oils—a work for which I had not the proper appliances in California—that I began to suspect that there were sulphur compounds present, and at last discovered that, with the thermometer bulb immersed in the condensing vapor, even at a temperature as low as 100° C., the distillates were decomposed and hydrogen sulphide disengaged. This decomposition of the oil was accompanied by a deposition in the flask of carbon, or a compound so rich in carbon that it remained undissolved in either the distillate or residual oil, and also by condensation of the residual molecule, as indicated by a continual rise in the boiling point of the oil remaining in the flask.

These observations have led me to conclude that sulphur as well as nitrogen plays a part in the changes which are active in the natural conversion of petroleum, through maltha, into asphaltum. That the esters exist as acid salts of the basic oils is quite probable; that polymerization of the molecules occurs to some extent cannot be doubted; that decomposition of the sulphur compounds takes place very slowly and at comparatively low temperatures with condensation of the residual molecules is almost certain; and that removal of hydrogen in the oil through deoxidation of the sulphates in the water with which the bitumens are in constant contact, with substitution of sulphur, may all be accepted as the prime factors of the problem involved in these changes. The lines of investigation above indicated have led me to some very interesting work upon the sulphur content of other bitumens than petroleum, which work is as yet incomplete.

Closely related to these factors are some observations made during my last visit to California. It was noticed that when the oils conveyed through pipe lines were distilled in summer, the yield of naphtha was much less than was obtained from the same oils in winter, although the extremes of temperature were not great. Upon investigation I found that in October, 1894, the oil, flowing through the blackened pipes laid upon the surface, was discharged into the tanks at a temperature of 90° F. I also found that an oil fresh from a well, kept in an open vessel at a temperature of about 100° F. for four days, ceased to lose weight and decreased in volume twenty-five per cent. In another experiment, one litre of oil was exposed to the sun in a pan placed in a window seat for three days. The temperature was at no time above 90° F., and over half of the time was below 70° F. The loss was twenty per cent. by volume, and the specific gravity changed from 28.5° B to 20.2° B. These results show that at the surface, natural evaporation is also a potent factor in the conversion of petroleum into maltha and asphaltum.

I wish to note here several facts of a different order bearing upon these questions. In 1865–6 the carcasses of several whales were lying half buried in the sand of the Pacific coast, between Point Conception and Ventura, California. They furnished food for numerous vultures and buzzards, and while the odor was not agreeable, it was the odor of rancid fat rather than of putrid flesh. During the summer of 1894 a vast number, weighing many tons, of deep sea fish, in a dying condition, came ashore upon that same coast for at least two hundred miles. Many of these fish were of large size, and among other species was a basking shark, twenty-six feet in length. An examination by one of the officers of the State Fish Commission led to the discovery that the gills of these fish were more or less filled with bitumen, which constantly rises from the bed of the ocean off this coast. The destruction of animal life was enormous. The first gale with a high tide buried nearly all of the fish in the sand of the beach. Complete skeletons of whales have been repeatedly discovered in the petroleum-bearing strata of that region, some of them saturated with bitumen.

One hundred miles due north of this coast, on the other side of the Coast Ranges, I have examined some of the most extensive veins of asphaltum yet discovered. They have been traced across the country continuously for miles and have been mined to a depth of more than three hundred feet. In chemical composition the asphaltum bears a specific relation to the petroleums of Ventura county. They both contain the esters of the pyridin bases. These asphaltum veins lie on one side of and irregularly parallel with a stratum of sandstone, which, like all of the strata of that region, stands nearly vertical. Along this sandstone stratum bitumen exudes for a long distance. Against it, and on the other side of it, rests a bed of infusorial earth, at least 1000 feet in thickness, in some places saturated with bitumen, but for the most part clean and white. These formations extend across the country, parallel for miles with the general trend of the Coast Ranges. Enormous springs of maltha, issuing therefrom at intervals, have produced at several points flood-plains of asphaltum that fill the small valleys like a glacier, many feet in depth and square miles in extent. The maltha is invariably accompanied with water, and at several points there are evidences that at some period in the past history of those outflows the springs that are now cold have been gigantic hot springs of silicated water, similar to those that I believe produced the famous Pitch Lake of Trinidad.

I went to Trinidad prepared to find abundant evidence of the direct conversion of wood into bitumen, as described by Wall and Sawkins. I saw nothing of the kind; nor could I find any one else who had. A superstition among the natives ascribes to the black mangrove the power of secreting bitumen. This shrub grows with its roots in sea water and often covered with oysters. The movement of the tide, the most nearly eternal phenomenon in nature, bears the bitumen that rises from the bottom of the sea against the oyster shells, and their jagged edges gather the floating particles. The entire deposit of pitch, both within and without the lake, contains on an average ten per cent. of partially decayed vegetation, and also an amount, difficult to estimate, of branches, trunks and stumps of trees, some of the latter of enormous size, much larger than any now standing in the vicinity. I did not see the outcrop of the lignite bed to the south of the lake that dips at an angle that would send it under the lake, as described by Manross, but I was told by one who had seen it, that this lignite bed, twelve feet in thickness, contained branches, trunks and stumps of trees that were in exactly the same condition as those found in the pitch—that is, they were still wood—not having been changed into lignite, and therefore not capable of being distilled by hot silicated water into pitch.

The circumstances of my life have brought me into personal contact with deposits of bitumen over a very wide area, and under such conditions as have afforded me very unusual opportunities for a careful study of all the phenomena attending the appearance of bitumen at the surface of the earth; the result of which has been to confirm the opinion that I have heretofore expressed, that, in the majority of instances, bitumens, from natural gas to asphaltum, are, where we now find them, distillates. In making this declaration I do not wish to be understood as calling in question the correctness of either the observations or opinions of those who have reached different conclusions.

Perhaps fifty years from now our ghosts may sit here with our grandchildren and hear them dogmatize concerning the origin of bitumen. For myself, the longer I study the subject and the wider my experience becomes, the less I am prepared to assert that any formula is capable of universal application. I would therefore suggest, that, as we now find them, bitumens are in some instances still where they were originally produced by a process of decomposition of animal remains, that is at present being illustrated on a small scale in the shallow bays of the Red Sea. Further, that other deposits contain primary distillates from the vegetable and animal remains enclosed in geological formations that have been invaded by heat, steam and pressure in past periods of the earth's history; and finally, that in some instances, as we now know them, bitumens have been transferred and stored by a secondary invasion of bituminous deposits by heat, steam and pressure. The details of these various movements await for their expression a vast amount of chemical and geological research by those who are to come after us.

A SUGGESTION AS TO THE ORIGIN OF PENNSYLVANIA PETROLEUM.

BY DAVID T. DAY.

(*Read February 5, 1897.*)

The three general classes of theories as to the origin of petroleum are so well known as to call for no especial description. I refer to (1) the inorganic origin by the action of water on metallic carbides; (2) by the slow decomposition of vegetable remains with insufficient supply of air, with or without simultaneous production of coal; and (3) the distillation of the fatty portion of anima organisms under pressure, in accordance with the discoveries generally credited to Engler.

It is pleasant, however, to recall attention to the fact, which has frequently been lost sight of, that Warren and Storer first distilled petroleum from animal fats years before; that is by the distillation of menhaden oil soaps under pressure they made good kerosene and actually sold the product—an achievement remarkable for the time at which it was done and gratifying to us as the work of American investigators and far in advance of any similar work abroad. The work of the German chemist, Engler, is thus simply confirmatory, and in extension, of what had been already done in this country.

Concerning these theories of origin, it seems to me extremely probable that the conditions required for the production of bitumens by inorganic means must have occurred repeatedly in the earth's crust, and that, therefore, bitumens have been formed by such means. The evidence of the actual occurrence of bitumens produced from inorganic sources is not complete, but in addition to the bitumens occurring in trap rock in eastern New York and Connecticut, it is well to call attention to the fact that water associated with the Trinidad asphaltum has been shown by Mr. Clifford Richardson to contain significant amounts of boracic acid compounds, which is some evidence of volcanic origin. Again, bitumens occur in the vein quartz of quicksilver deposits in various parts of the world, and such occurrences are frequent in California.

If we take into consideration the organic life available for yielding petroleum, it seems easier to believe that the supply of oils found in the Silurian limestones has come from the distillation of fats associated with *animal* remains, than that they were derived from *vegetable* matter.

On the other hand, general opinion tends to associate the Pennsylvania oils with a vegetable source, and it is against this that I wish to make a few suggestions, based upon the observations of Rev. John N. MacGonigle, formerly a stratigrapher in the employ of the Forest Oil Co. Mr. MacGonigle's opinion is that the Pennsylvania oils were originally contained in the Silurian measures, as are the Ohio oils, and that a redistillation, accompanied by a transfer to rocks of the Devonian age, resulted in a change of the character of the oils.

In his own words, as written to me, Mr. MacGonigle states:

"It may be admitted that the marvelous deposits found in the Trenton and Clinton limestones and widely diffused in the other limestones and shales of the Silurian period are indigenous. It is a well-known fact that the series constituting the Silurian age, as the result of one of nature's wonderful convulsions, sweeps toward the eastward under the Devonian and Carboniferous areas, forming the floor of the basin in which the measures of these periods were deposited. The uplift which forms the Appalachian chain occurred at the close of the Carboniferous period. This was due directly to heat action. It is, therefore, at least suggested that the petroleums of Pennsylvania owe their origin to the effect of this heat upon the underlying limestones and shales of the Silurian age. The theory is, that the same force which caused the Appalachian chain to uplift, passing through the limestones and shales of the Silurian age at a modified temperature, distilled the oil already contained in these shales and conglomerate sands of the Devonian age, where it was condensed and filtered and found its home in the open, porous conglomerates which characterize the Catskill, Portage and Chemung periods of the Devonian age.

"There are many reasons why this theory seems to be more satisfactory, to me, than any of the others. In the first place, the peculiar characteristic of the Silurian oil is its well-known sulphur compound, which for many years presented almost insurmountable difficulty to the refiner. The low specific gravity is its second characteristic quality, and a uniform quality marks it everywhere. In the oils of the Pennsylvania region and the Devonian horizon we have a range of color from light amber to black, a higher specific gravity and almost entire freedom from sulphur compounds.

"In addition to what has been said with reference to the Silurian period, it may also be added that at its top lies the Corniferous limestone, which is the source of the petroleum of western Canada. This limestone has been reached by the drill in Pennsylvania in the well at Erie and at the Conway well, which, piercing the Venango-Butler group, reaches the Corniferous limestone. In neither case was any trace of oil discovered in the Canadian measure. In addition to the varieties of color and specific gravity, together with the freedom from sulphur which characterizes the Pennsylvania petroleums and indicates the process of filtering, it is also extremely doubtful whether the measures of the Devonian age and particularly those in which the Pennsylvania petroleums are deposited, ever contained any life which could have given rise to the petroleum. It is generally conceded that the great volume of the oil which is found in the Trenton and Clinton limestones is due to chemical action upon the organic life of that period. The experience which has been the result of many years of drilling in Pennsylvania has failed to discover any evidence of organic life in the period in which the

Pennsylvania measures were deposited that even suggest a sufficient source for the great bodies of petroleum which have already been brought to the surface in that region."

In a communication received from Mr. MacGonigle to-day he calls attention to the fact that a line drawn from Brady's Bend to Waynesborough, Pa., will show the eastern limit of profitable oil pools in that region. East of that line, however, some of the most prolific gas pools of Pennsylvania have been developed, notably, Murrysville, Grapeville, Latrobe, etc. This would at least suggest a side light in favor of the theory above mentioned, showing that as the area approached the line of greatest upheaval and consequently greatest temperature, the volatile oil (gas) was, without condensation, retained in its condition as it came up from Silurian horizons.

I believe that this theory of Mr. MacGonigle is more probable than any that has been advanced as to the present condition of oil in Pennsylvania. It does not seem, however, necessary to introduce the idea of any redistillation whatever from the fact that if sufficient cracks existed in the cover over the Silurian limestones, the oils would leak through the shales to their present position without the application of any heat, and by experimental work it may easily be demonstrated that if we saturate a limestone such as the Trenton limestone with the oils characteristic of that rock and exert slight pressure upon it, so that it may flow upward through finely divided clay, it is easy to change it in its color to oils similar in appearance to the Pennsylvania oils, the oil which first filters through being lightest in color and the following oils growing darker. Further, if we examine oils in the new fields of Tennessee and Kentucky, we find as we go lower that oils which were light in color at the surface are dark in color when we go through the shales and find them in the lower limestones. In fact it is possible to watch the process of filtration from dark oils similar to the Ohio sulphur-bearing oils to the lighter oils of Pennsylvania found nearer the surface. The means by which the sulphur has been taken from the Ohio oil is far more difficult to explain, although the ease by which sulphur compounds and unsaturated compounds can be removed from petroleum by the use of aluminum chloride points to the chloride of some metal as a means by which this may have been accomplished.

ON THE GENESIS OF NATURAL GAS AND PETROLEUM.

BY FRANCIS C. PHILLIPS.

(Read February 5, 1897.)

If it were possible to demonstrate that the original source of petroleum and natural gas is to be looked for in the rock strata in which they are now found to occur, an important advance could be made towards the establishment of a satisfactory hypothesis to account for the genesis of these hydrocarbons in nature.

It has often been supposed that the relationship of the hydrocarbons to the rocks in which they occur is of an intimate kind, and that the geological record should supply all the data upon which a conclusion as to the origin of gas and oil is to be based. It does not necessarily follow, however, that they are products of Devonian or Silurian time because of their association with certain sandstones, limestones or shales.

The presence of a gaseous or liquid hydrocarbon in a particular rock is perhaps due to the fact that the region of this rock, on account of its open texture, has been one of least resistance to the movement of a fluid under pressure. It is possible that gas and petroleum may have invaded the Devonian strata from greater depths and that their present position is wholly due to the pressure to which they have at some former period been subjected.

Other circumstances may have been factors in determining their present location. An abundance of subterranean water may have caused a transfer to a higher level. Differences of temperature might involve a partial fractionation or distillation and removal to distant regions. Hydrocarbons of different character and from different sources might become mingled and thus intrinsic signs of different modes of origin be obliterated. In view of these inherent difficulties, which impede a solution as viewed from the geological standpoint, the question seems to resolve itself for the present into a broader but less definite one which might be formulated thus: What are the chemical processes which, being logically assumed in connection with known facts of geology, could have produced from the compounds of carbon and hydrogen in the rocks the vast quantities of bitumen, petroleum and natural gas?

Of the hypotheses proposed many have been based upon phenomena which are more or less local when geologically considered, even if occurring in terranes of wide extent. One hypothesis attributes to petroleum and natural gas an origin almost cosmical.

This hypothesis, suggested by Berthelot and afterwards developed by Mendeléeff (*Principles of Chemistry*, Vol. i, p. 364), and restated by this author in 1889, supposes that metallic carbides have been produced deep in or below the earth's crust, and that these carbides have been decomposed by steam giving rise to the various hydrocarbons of oil and gas. Mendeléeff supposes that carbides of the heavier metals, and among these especially iron, have been mainly instrumental in the process. The correctness of this hypothesis, which depends upon so direct an appeal to chemical facts, must be tested by a consideration of the laws of chemistry in so far as they bear upon the question.

According to the experiments of Moissan (*Compts Rendus*, Vol. 122, p. 1462), a few only of the metals are capable of forming definite carbides, even at the temperature of the electric arc. These are chiefly the alkali, alkaline earth and earth metals. Aluminum and beryllium are the only metals whose carbides yield a hydrocarbon of the paraffin series alone (methane) on decomposition by water. The action of water upon the carbides of the metals of the alkalies and alkaline earths produces acetylenes. In the case of the carbides of some heavier metals methane is produced in admixture with free hydrogen and ethylene. The results of this author's experiments would seem to lead to the conclusion that the carbides of the earth metals only can be assumed to have participated in the process of petroleum and gas formation, in accordance with Mendeléeff's hypothesis, if the chemical composition of natural gas as found in western Pennsylvania is taken into consideration.

There are few elements known to chemistry whose relationships towards carbon at high temperatures are better known than iron. The action of steam upon iron in its pure state and when in combination with carbon is also sufficiently well understood to justify a criticism of the hypothesis upon chemical grounds. It is a fact of importance that the product of the action of superheated steam upon cast iron consists mainly of free hydrogen with small quantities of hydrocarbons, including olefins, paraffins and others of unsaturated character.

It may be assumed, but hypothetically, that iron exists in the rocks in form of a carbide richer in carbon than is producible in the electric furnace, and therefore resembling the carbides of aluminum as regards its action upon water. In such case a gas somewhat similar to natural gas might result. Published analysis of meteoric iron and of iron found in plutonic rocks do not tend to show, however, that the iron found in nature ever contains carbon in such quantity as to lead to the belief that a definite carbide of this metal exists comparable to the carbides of aluminum, akaline earth, and alkali metals.

If aluminum carbide and the carbides of related metals are to be regarded as the source of natural gas, we must look for the occurrence of the lighter metals at depths at which the hypothesis of Mendeléeff would require us to suppose that the heavy metals predominate. It seems, therefore, probable that a few only of the metals in form of carbides could have been concerned in the production of natural gas, and these are the very metals which on account of their lightness are supposed by this hypothesis to give place to those of high specific gravity in regions where the chemical changes in question have occurred.

On account of its stronger affinity for oxygen, aluminum may be supposed under all conditions tending towards oxidation to assume the form of an oxide more readily than iron, and where aluminum occurs in presence of the heavier metals it will probably precede these in the order of time in uniting with oxygen. But its oxidation would remove it from the sphere of action leading to the production of hydrocarbons.

The conclusion seems justified that where aluminum occurs in a metallic state, or as a carbide, below or in the earth's crust, the heavy metals will also abound and notably iron.

If the chemical composition of natural gas is such as to warrant the belief that its production was due to the action of steam upon iron carbide, the hypothesis of Mendeléeff would at once receive strong support. If, on the other hand, chemical considerations show that iron cannot have been concerned in the process, the question then arises, Why has iron carbide been suppressed in the subterranean reactions giving origin to natural gas?

The term iron carbide has here been used to signify iron containing a little carbon, such as cast iron, but not implying a real compound containing iron and carbon in atomic proportions.

Analytical data concerning natural gas drawn from deep-lying strata must prove of importance in the discussion of the subject. The hypothesis of Mendeléeff would suggest that if free hydrogen occurs among the hydrocarbons contained in any geological formation it must be looked for in those strata which are nearest above the Archæan rocks, and where protection against loss by diffusion upward is as nearly as possible assured by great thickness of compact overlying beds.

Believing the composition of natural gas from formations of considerable depth to be a matter of interest, some tests were made during August, 1896, of natural gas from a well drilled down through the Trenton limestone at Stevensville, county of Welland, Ontario, Canada. This well is twenty-nine hundred feet deep and stratified formations below its bottom are locally of slight depth, so that, according to Mr. E. Coste, the engineer for the gas company, the drill has in the case of this well penetrated to within a short distance only of the Archæan rocks. Shales sixteen hundred feet in thickness shut off possible communication between the Trenton limestone and the upper gas-producing rocks (the Medina sandstone, Clinton limestone and Niagara limestone), and there seemed every reason to suppose that the gas was derived exclusively from very deep-lying measures. The tests were made at the well, and thus the possibility of errors due to leakage during transportation of a sample were avoided. The method employed I have described in the *American Chemical Journal* for 1894, page 258.

Tests were also made at the well by methods which have been devised for such purposes, and which have been described in the same volume of the journal named, for acetylene and carbon monoxide. The results of all these trials were negative. Numerous tests have been made of gas from wells scattered over various parts of western Pennsylvania which seem to justify the conclusion that free hydrogen, acetylene and carbon monoxide are not found in the natural gas of the region.

The absence of free hydrogen in natural gas might be explained upon the assumption that although originally present, it has, by reason of its extreme lightness and ready diffusibility passed out through overlying rock strata and made its way to the upper regions of the atmosphere. In such case we must suppose that as a result of the production of free hydrogen in the interior of the earth, the atmosphere now contains in its more rarified portion a considerable and gradually increasing volume of this very light gas.

Mendeléeff's hypothesis implies that the production of natural gas still continues, there being no reason to suppose that the iron or other metallic carbides below the earth's surface are exhausted. Consequently much importance must be attached to the question of the presence of free hydrogen.

Accepting provisionally the hypothesis of Mendeléeff, it may be asserted that if natural gas is a contemporaneous product sufficient time has not yet elapsed for the escape by diffusion of the free hydrogen through some hundreds or thousands of feet of shales and limestones. The free hydrogen originally present should still occur in the gas of different regions and be recognizable by chemical tests. If, on the other hand, natural gas is a stored product, shut in for long ages, it might seem possible that comparatively impervious rock strata would not have sufficed to prevent the escape of this highly diffusible constituent in the course of time.

No hypothesis regarding the origin of natural gas can be accepted as satisfactory if it should require the assumption that the chemical changes involved in the process are such as to lead to the production of much free hydrogen, unless it can be positively demonstrated that free hydrogen occurs as a common constituent of the gas which flows from a drill hole.

The foregoing criticisms have been directed more particularly to the hypothesis in so far as it relates to natural gas. The author of the hypothesis has apparently avoided a distinction between natural gas and petroleum, and to the various hydrocarbons, liquid or gaseous, he assigns a common origin. It has been common to consider such compounds as closely related genetically. Yet this supposition may not have sufficient basis. Mabery (*American Chemical Journal*, 1896, p. 43) has shown that benzene and its homologues occur in some of the Ohio and Canadian petroleums. Lengfeld and O'Neill (*American Chemical Journal*, 1893, p. 19) have also discovered members of the same series of hydrocarbons in petroleum from southern California. Similar observations have been made by other authors.

The composition of natural gas is such as to suggest that it has been produced by reactions occurring at low temperature, and there is reason to suppose that it has not been exposed to temperatures exceeding 500° C., since the time of its formation, as experiments demonstrate that at temperatures ranging from this point up to that of melting gold, its constituents suffer more or less complete dissociation, yielding hydrogen and carbon together with small quantities of unsaturated hydrocarbons, notably acetylene. On the other hand, petroleum has been shown by the important researches of Mabery to contain a series of hydrocarbons which are usually characteristic of reactions at high temperatures. The fact that such hydrocarbons occur in petroleum, whether in small or large quantities, is of very great interest and should have due weight in the selection of any hypothesis proposed to account for its origin. At present this fact can hardly be considered to furnish evidence either for or against the views of Mendeléeff in regard to the origin of natural gas.

ON THE OCCURRENCE OF PETROLEUM IN THE CAVITIES OF FOSSILS.

BY FRANCIS C. PHILLIPS.

(*Read February 5, 1897.*)

In the study of geological facts bearing upon the history of petroleum, much interest has been aroused during recent times by the discovery of petroleum enclosures in the cavities of fossils in limestone rocks. Such occurrences, observed in many places, and in deposits of different geological age, from the Silurian onward, have been regarded as furnishing proof that the genesis of oil is to be attributed to chemical changes taking place in the tissues of the original organism of the fossil, and therefore as strengthening a commonly accepted belief that the hydrocarbons contained in the rocks have originated from animal remains stored in the sediments which afterwards became consolidated into rock.

The relationship suggested between the petroleum and the fossils is all the more interesting and important since the oil-bearing sand rocks of the Devonian age do not, as a rule, contain remains of animal life, and furnish no satisfactory clues as to the origin of oil and gas. As tending to confirm the evidence which such facts have been supposed to furnish, numerous instances have been cited where hydrocarbons are apparently produced from remains of more recent animal life, as in coral reefs and in the accumulations of organic remains buried under marine or fluviatile sediments. In certain districts local accumulations have apparently led to the formation of petroleum and natural gas, and where evidence of so direct a character is at hand it has been argued that chemical changes of similar kind have been concerned in the production of hydrocarbons upon a larger scale in the rocks. But the fact most suggestive of a genetic relationship between the hydrocarbons of the rocks and the tissues of animal bodies is found in the frequent association of petroleum and bitumen with fossil remains.

A remarkable instance of this kind has been discovered at Williamsville, Niagara county, N. Y., by Mr. F. K. Mixer, of Buffalo. Corals in large masses, constituting a reef of considerable proportions, have been exposed in a limestone quarry at this place. The structure of the coral is well preserved and its rounded forms are standing erect as they grew in the original reef. In many parts the cells contain petroleum in a somewhat thickened or dried condition and the walls of the fossil seem to be saturated with oil. In other parts of the reef the cells contain a black substance resembling pitch or asphaltum, the color of which gives great distinctness to the delicate white lace-like partitions separating the cells. The distribution of petroleum and solid bitumen throughout the coral is somewhat irregular.

In viewing this reef, as it stands exposed in the quarry, various questions suggest themselves as to the origin of the hydrocarbons. If these have resulted from the carbon and hydrogen of the bodies of the polyps, how has it occurred that the organic matters were converted into paraffins instead of undergoing the usual process of oxidation and decay? The growth of the reef was undoubtedly slow, as a portion only of the polyps could have been living at any given time, the greater number of the cells being empty, the quantity of animal matter available for petroleum production must always have been small as compared with the total extent of the reef, and being scattered among separate cells oxidation of the remains of the isolated polyps would have been more likely to occur than their accumulation in masses. There does not seem to be any reason in this case for supposing that the corals in their living state were buried under masses of sediment. On the contrary, the limestone extending around and above the corals indicates a period of quiet and clear water. It is, therefore, difficult to understand how the soft tissues of dead coral animals could have been protected against destructive oxidation.

Pieces of this fossil taken from the quarry are on examination readily seen to contain an amount of petroleum at least equal in bulk to the cells of the coral. The solid bitumen occurring in other parts suffices to nearly fill the cells. These facts would render it difficult to account for the hydrocarbons on the supposition that they are due to chemical changes occurring in the tissues of the original organisms.

Le Bel (*Notice sur les Gisements de petrole à Pechelbronn*, Colmar, 1885, p. 4) has observed that fossils frequently contain in their cavities a quantity of petroleum greater than could be produced from the organic matter of the original animal, even supposing that this organic matter had been converted wholly into petroleum.

Fraas (Jaccard, *Le Petrole*, *1895*, p. 60), in describing the occurrence of petroleum in a coral reef in the Red Sea, refers to the fact that oil collects in parts of the reef growing in shallow clear water and states that this oil is so abundant that it has been carried by Bedouins to Suez, where in 1868 it had become an article of commerce. Fraas believes that the oil is being produced by the decomposition of the organisms of the coral.

If the source of this petroleum is correctly interpreted, its occurrence under such conditions can hardly be considered to represent an isolated case. The reactions which take place during the conversion of animal remains into petroleum must be typical of changes occurring elsewhere, and must result normally under given conditions as to temperature, pressure and oxidizing influences. Wherever the same conditions exist in other reefs they should give rise to a similar constant production of petroleum and we should be justified in speaking of a "petroleum fermentation" coördinate with other naturally occurring organic changes.

It seems doubtful whether this petroleum can have originated in the coral where it is found and it is improbable that such an occurrence can serve to explain the origin of hydrocarbons in the Silurian fossils. I have been unable to learn that petroleum is found in the reefs at Bermuda. Dr. W. H. Dall, of the Smithsonian Institution, informs me that no occurrence of petroleum has been reported in the reefs of the Florida coast. If in the case of the Silurian coral at Williamsville the process of conversion into hydrocarbons was rapidly completed after the destruction of the animals, the oil would have floated to the surface of the water and little would be left to impregnate the calcareous skeleton. If, on the other hand, the process was continued until the organic matters were buried under deep sediments and exposure to oxidation had ceased, then more distinct signs of a deposit of sediment over the entire reef should be looked for.

The conditions for effective oxidation of organic matters are rendered more complete under water by the presence of bacteria, and these must have aided greatly in promoting the final change of the tissues of the dead coral animals into nitrates, ammonia, carbon dioxide and water. In stream beds and under sediments the products of the decay of animal matters are mainly gaseous, and the contents of the coral cells must have been almost wholly lost in volatile form before a process of change into petroleum could have been begun in the much diminished residue of the original organisms.

It is possible that the occurrence of petroleum in the cells of a modern coral reef may find an explanation in a phenomenon often observed in the case of natural gas. I have elsewhere (*Journal of the American Chemical Society*, 1895, p. 801) called attention to the fact that on stirring the gravel which lies at the bottom of many streams in western Pennsylvania, it is common to find that gas bubbles are disengaged, and that such an accumulation of gas may occur where the stream flows over sandstone, covered by gravel a few inches only in depth, and where the character of the gravel renders it unlikely that gas could have originated locally. In such cases it is probable that the occurrence of gaseous hydrocarbons is due to an escape to the surface from deep-lying rock strata.

Petroleum escaping from the interstices of a rock might accumulate in the cavities and cells of dead corals. A slow oozing of petroleum from the surface of the ground is a well-known phenomenon in various parts of the oil regions.

The occurrence of petroleum in cavities of fossils might be traced to a former condition of wide distribution of oil throughout the rock, that is, in a form in which it is known to be present in limestones and shales in many places. The gradual access of moisture to the pores of a rock so impregnated would tend to cause a slow displacement of the oil. Water, insufficient to appear in liquid form upon a surface of fracture, might still suffice, as it gradually saturated the rock under the influence of capillary attraction, or of pressure, to displace the oil and cause it to accumulate in liquid form in the cavities of fossils or in other open spaces. Moisture in such quantity as is absorbed by many dense rocks would tend slowly to remove liquid hydrocarbons, just as it might drive them from the cells of vegetable tissue. The region of least resistance to the movement of the oil would be a cavity. The accumulation of oil in open spaces in fossils would thus result from its displacement from adjacent, or perhaps distant, parts of the rock by water, which would tend to produce a retreat of the oil. If thus impelled by the movement of moisture through the rock the oil would gradually assume the liquid form if it passed into a cavity. The cells of corals and other open spaces might thus become reservoirs capable of holding collectively considerable quantities of oil.

It is true that before the original sediment became hardened into rock, the proportion of water present must have been considerable. In accordance with a commonly accepted view the process of petroleum formation was not completed until long after the sediments with their enclosed organic matters had been consolidated. The oil would then have been expelled from the rock, little by little, as it was being gradually produced. In this case also the movement of the oil might have led to its being caught in liquid form in cavities, or if it oozed out at the surface of the rock stratum it might have been absorbed by a more porous rock, or caused by pressure of water to flow off through sand-rocks of more open texture. The movement of the oil through the rock, displaced from the interstices in which it had originally collected, would have been accelerated as the transition from solid organic tissues to liquid oil had become advanced.

Water, if present in a rock of fine texture, could not by the action of capillarity alone be drawn upward so as to collect in liquid form in a cavity. The same statement is true of petroleum. But the presence of moisture in the interstices of a rock in which petroleum is being generated or in which it is stored in minute pores or spaces might lead to a gradual accumulation of oil from the bulk of the rock into relatively larger spaces such as the cavities of fossils.

Jaccard (*Le Petrole*, 1895, p. 134) has described the occurrence of bitumen in the cavities of fossil mollusks in the Val de Travers in the Jura mountains. Such cases might be regarded as representing a later stage in a series of changes, the original liquid petroleum having passed into solid bitumen long after it was accumulated in cavities, where its solid condition would tend to its permanent preservation.

The sedimentary limestones contain frequently crystalline calcite cementing together the grains of amorphous mineral matter. Changes in temperature, causing unequal expansion of this calcite in different directions, by reason of the form of its crystals, might in the course of time modify the process by changing the internal structure of the rock. The presence of salt in solution and the solvent action of carbonic acid would no doubt exert an important influence, although its nature could not be foreseen.

The occurrence of petroleum in the fossil shells of mollusks and in the cells of corals would then have no more geological significance than its occurrence in geodes, or in cavities in rocks, or the presence of solid bitumen in hollow quartz crystals or in sphalerite, as all such cases are perhaps attributable to one and the same source, namely, to its presence formerly in a state of wide distribution in the pores of the rock.

ON THE COMPOSITION OF AMERICAN PETROLEUM.

BY CHARLES F. MABERY.

(*Read February 5, 1897.*)

Petroleum is found in Pennsylvania in sandstones of various formations; in southern Ohio in the Berea grit and other sands; in Ohio in the Trenton limestone; in Canada in the Corniferous sandstone; in California, Texas, Colorado, and other American fields in shales and sandstone formations, which represent in general the geological strata in which are the various oil fields in Russia, Roumania, Germany and Austria, Japan, India, etc. Crude oils show great variation in their physical properties, such as color, specific gravity and odor, and differences in their chemical reactions depending on variation in composition.

The first systematic investigation for the purpose of ascertaining the composition of American petroleum was made by Pelouze and Cahours, who referred the entire body of crude oil, including paraffine, to the series homologous with marsh gas, C_nH_{2n+2}. At about the same time, 1862, C. M. Warren began a study of Pennsylvania oil, in which he subjected the various refinery distillates to a prolonged course of fractional distillations in a special form of regulated condenser which he devised for such distillations. He separated distillates at 0°, 8°–9°, 30°, 37°, 61°, 68°, 90°, 98°, 119°.5, 127°.5 and at 150°.8, of the series C_nH_{2n+2}, and of the series C_nH_{2n}, members at 174°.9, 195°.8, 216°.2.

In connection with the discovery by synthesis of the hydrocarbons, hexane and heptane, Schorlemmer, in 1865, separated the hydrocarbons C_6H_{14} and C_7H_{18}, boiling at 60° and 90°. After Warren's results were published, he admitted the others at 38°, 68° and 98°. Schorlemmer also separated an octane at 125°. He corrected the work of Pelouze and Cahours with reference to boiling points. At about the same time in 1880, Beilstein and Kurbatiff and Schutzenberger and Jonine undertook an examination of the Caucasus petroleum, and identified hexahydro-aromatic compounds at 97° and at 118°. The former chemists also found hexahydroisoxylol at 118° in American petroleum. Soon afterward Markownikoff separated a long series of the naphthenes at 69°, 97°, 118°.5, 136°, 162°, 182°, 216°, and several members with higher boiling points. Markownikoff also found numerous aromatic hydrocarbons of the series C_nH_{2n-6}, and of other series with less hydrogen.

Various examinations of lesser magnitude have been undertaken, in a more or less superficial manner. Engler showed the presence in small quantities of mesitylene and other aromatic hydrocarbons in Pennsylvania petroleum. Among other bodies present in small amounts are the nitrogen compounds, the oxygen compounds, concerning which there is still some question as to the form in which they exist in the crude oil. Recently Zaloziecky has attempted to show the presence of the terpenes, which I recognized by their odor seven years ago (*Proc. Amer. Acad.*, Vol. xxv, 1890). I began the study of petroleum in 1884, and in 1885, soon after the Trenton limestone oil was discovered, I undertook to separate the sulphur constituents. The sulphur compounds in Canadian petroleum were undertaken in 1891, and are still in progress. In 1893, through aid granted by the C. M. Warren Committee of the American Academy of Arts and Sciences, the scope of my work was extended to include broadly the composition of American petroleums with especial reference to Pennsylvania, Ohio and Canadian crude oils. The great field for research includes the portions of petroleum with boiling points above 220°, but there are serious difficulties in the way of reaching satisfactory results with these bodies. In a paper recently published in the Proceedings of the American Academy an account is given of the composition of Pennsylvania, Ohio, Canadian petroleums below 220°. The series C_nH_{2n+2} represents the main body of Pennsylvania and Ohio oils, and of Canadian oil below 195°. Aromatic hydrocarbons of the series C_nH_{2n-6}, are present in considerable quantities.

Careful study of petroleum from different sources with reference to its occurrence and composition indicates that no precise classification of crude oils can be based on these particular features. Accepting Pennsylvania petroleum as typical in its occurrence as a sandstone oil, in its composition, and in the fact that it is a low sulphur oil, even the numerous varieties from different sections and different strata in the same field present great variations in the proportions of the individual constituents. Such oils as the light amber variety from the Berea grit sandstone (Mabery & Dunn, *Amer. Chem. Journ.*, xviii, 1896) in southern Ohio and Virginia show larger proportions of volatile constituents below 150°, and those distilling above 250°, but less of the intermediary constituents which are looked on in refining as the more valuable illuminants. In attempting a classification with reference to the proportion of sulphur compounds, it appears that the principal components of the typical Pennsylvania oil form the main body of such oils as those from Ohio Trenton limestone, and the Canadian Corniferous limestone, although below 150°, in the limestone oils the proportions of the hydrocarbons C_nH_{2n+2} are relatively smaller and the aromatic hydrocarbons C_nH_{2n-6} relatively larger. These statements are made on the basis of results recently published (Mabery, *Proc. Amer. Acad.*, xxxii, 131). Study of the higher portions of Pennsylvania petroleum above 220° is now in progress for the purpose of separating without decomposition by distillation in vacuo, with consequent diminution of boiling points and exclusion of air, the constituents between 216° and 400°. This work has progressed sufficiently to show that the aromatic hydrocarbons of the series C_nH_{2n-6}, form only a comparatively small proportion of the distillates at least within the lower limits of temperature. It should be borne in mind that nothing is known concerning the principal or the subordinate constituents of American petroleum above 250°, except the possible presence of certain aromatic hydrocarbons, and these were recognized in products of ordinary distillation in which there is invariably much decomposition. To illustrate the effect of air at high temperatures on distillates with high boiling points, in a course of distillations in vacuo of Russian crude oil, accidentally air was allowed to enter a still in which distillation was proceeding without decomposition under a tension of 50 mm. at 250°. As soon as the air came into contact with the hot vapors, there was a violent explosion sufficient to send the thermometer out of the still and shatter it against a brick wall several feet distant. Air let into a still under similar conditions in which Pennsylvania oil is distilling usually causes flashes of light, but no explosion. From these observations it is evident that the advantage of distillation in vacuum depends as much at least on exclusion of air as on the reduction in temperature.

Definite statements relating to the composition of petroleum from different American fields must, at present, be limited to the distillates below 216°. But so far as it is possible to draw conclusions from data collected there seems to be no possibility of distinction based on geological occurrence and composition. High percentages of sulphur constituents are usually associated with limestone formations as the source of occurrence of the crude oils. But study of the varieties of crude oil from widely different sources leaves no basis for this distinction. A petroleum from South America occurring in a system of shales and sandstones contained 0.70 per cent. of sulphur (Mabery and Kittelberger, *Proc. Amer. Acad.*, xxxii, 185). Another variety from Oregon having no connection with a limestone formation also gave a high percentage, 1.19 per cent of sulphur. A specimen of petroleum from Japan, now under examination in this laboratory, gave 0.5 per cent. of sulphur. The immense deposits of petroleum in Roumania occurring in shales and sandstones are mostly high sulphur oils. No distinction can therefore be based on sulphur contents and geological occurrence.

It seems doubtful whether a distinction can be based on specific gravity and geological occurrence. The Pennsylvania oils differ from most others in their low specific gravity, varying in the main between 0.80 and 0.82; such light oils as the amber variety from Berea grit sandstone is as low in specific gravity as 0.79 (Mabery and Dunn, *American Chemical Journal*, 1896, 11). The limestone oils are higher, those from the Trenton limestone giving 0.82 to 0.85, and those from the Canadian Corniferous limestone 0.85 to 0.88. But the Russian oil, the South American oil mentioned above, the Japanese oil, and the Roumanian oil all show a high specific gravity. With reference to the proportion of sulphur contents and specific gravity, it seems that all the high sulphur oils have a high specific gravity.

There is some hope of arriving at a general system of classification on the basis of the series of hydrocarbons which constitutes the main body of the crude oils. While more must be known concerning the composition of the constituents with higher boiling points before such a distinction can be made with desirable precision, I have seen sufficient of the behavior of the higher constituents to believe that such a basis is reasonable. As types of such a classification I should select on the one hand Pennsylvania oil, and on the other, Russian oil from the Baku district. The difference in specific gravity of the crude oils is borne out by the difference in specific gravity of the corresponding distillates, and individual constituents with the same boiling points. The typical constituents of Pennsylvania oil, at least below 216°, are members of the series C_nH_{2n+2}, but the components of the Russian as defined by the researches of Markownikow are the naphthenes of the series C_nH_{2n}. With reference to the ethylene series C_nH_{2n}, which has seemed to be accepted by some as constituting the main body of American petroleum, so far as my observation has extended, those hydrocarbons are not contained in any petroleum, at least below 216°, in more than minute quantities. Results which I have yet to publish show that these bodies are contained only in small proportions in limestone oils.

A classification of pretroleum from all known sources evidently demands as its basis conclusive evidence as to the series of hydrocarbons of which each is chiefly composed. The methods to be pursued in reaching this knowledge have been indicated in my examination of Pennsylvania, Ohio and Canadian oils between 150 and 216 (*Proc. Amer. Acad.*, xxxii, 121). That the series C_nH_{2n+2}, constitutes the chief body of Pennsylvania crude oil below 150° was well established long ago by independent investigations. Above this point the evidence was less satisfactory. To accept the results of Pelouze and Cahours which continued the series C_nH_{2n+2} through the entire range of distillates to paraffine, it is necessary to ignore the fact that American petroleum is not composed exclusively of a single homologous series of hydrocarbons, but of a mixture of bodies that require for their separation, not only very prolonged fractional distillation, but searching and vigorous means of purification.

At the time when the French chemists conducted their investigations on American petroleum, both Pennsylvania and Canadian products were to be obtained in the European markets, especially in France, where Canadian oil seems to have been more easily obtained at times than Pennsylvania oil. In the papers of Pelouze and Cahours, allusions are made to American petroleum, and to Canadian petroleum. Their second paper (*Compt. Rend.*, 56, 505, 1863), begins with the following paragraph: "Dans un premier examen que nous avons fait des produits les plus volatils de l'huile provenant des forages qu'on pratique depuis quelques années sur plusieurs points de l'Amerique, et notement au Canada, nous avons signalé l'existenér d'un homologue du gaz des marais dont la composition est représentée par le formule $C_{12}H_{14} = 4$ vol. vap."

With no previous knowledge as to the properties of crude oils from these different sources it would not be surprising if they were used indiscriminately. At any rate an examination of the papers of Pelouze and Cahours does not reveal the source from which their crude oil was obtained. But a comparison of their results as to specific gravity and percentage composition, together with their method of purification, with the same properties of distillates more thoroughly purified (Mabery, *loc. cit.*, p. 171), presents conclusive evidence that Pelouze and Cahours had in hand, in at least a portion of their work, distillates from Canadian oil. Furthermore, in some of their distillates showing a higher specific gravity than it is possible to obtain after suitable purification, even from Canadian petroleum, analytical values correspond closely to the series C_nH_{2n+2}; $C_{12}H_{26}$ at 196°–200°, and $C_{13}H_{28}$ at 216°–218°. That Canadian crude oil was to be obtained in England at that time is evident from the work of Schorlemmer, who demonstrated the presence in oil from Canada of the aromatic hydrocarbons C_nH_{2n-6}.

The series C_nH_{2n}, found by Warren in Pennsylvania petroleum, has been accepted by some as showing the presence of the ethylene hydrocarbons, and by others as indicating the naphthenes. That the naphthenes are excluded below 216° in Pennsylvania oil by the wide difference in specific gravity has been pointed out (Mabery, *loc. cit.*, 125). The ethylene hydrocarbons are also excluded by the want of additive power in these distillates for the halogens.

Indeed, after removal of the aromatic hydrocarbons C_nH_{2n-6}, the series C_nH_{2n} disappears altogether from distillates within these limits, leaving the series C_nH_{2n+2}, as representing the main body of Pennsylvania petroleum within these limits. The individual representatives of this series, when properly collected by fractional distillation and purification, include a decane at 163°–164°, normal decane at 173°–174°, undecane at 195°–196°, and undecane at 214°–216°. From Canadian petroleum a hydrocarbon collects at 196°–197° whose percentage composition and molecular weight, as well as the composition of the monochlor-derivative, corresponds to the formula $C_{11}H_{22}$, and another at 214°–216°, with the formula $C_{12}H_{24}$. The composition of all these hydrocarbons was ascertained by analysis, molecular weight determinations, analysis of chlorine derivatives, and molecular weights of the chlorine derivatives.

The impression that the higher portions of Pennsylvania oil are composed of naphthenes was perhaps not wholly without a reasonable foundation. After finding hexahydroisoxylol in Russian oil Beilstein and Kurbatoff identified the same body in Pennsylvania oil. Since no further attempts were then made to ascertain the composition of the higher portions, it was natural to infer that the results of Warren leading to the series C_nH_{2n} should be best explained by assuming that his bodies were naphthenes. After the discovery of the naphthene series in Russian oil by Markownikoff, this belief was strengthened by the erroneous assertions of Hoefer and other anthors of German publications on petroleum that Markownikoff had established the naphthene series in Pennsylvania oil. A critical comparison of the specific gravity of Warren's hydrocarbons with those of Markownikoff without further work would have suggested doubts as to the presence of naphthenes in Pennsylvania oil at least below 216°.

It has long been an open question with oil men as to whether Ohio and Canadian petroleum is identical with Pennsylvania oil as regards the principal constituents. With respect to the portions distilling between 150° and 216°, this question has now been answered. The observed differences in the properties of distillates within these limits before purification concern, as has been shown, specific gravity and percentage composition. Before purification, however carefully the distillates have been separated by fractional distillation, analytical values correspond fairly well with the series C_nH_{2n}. After removal of the aromatic hydrocarbons the specific gravity is much reduced, and in the Pennsylvania distillates it corresponds to the specific gravity of the same hydrocarbons synthetically prepared. Similar changes are produced in composition, the series changing to C_nH_{2n+2}. The series of aromatic hydrocarbons is represented in all the oils under consideration by numerous hydrocarbons, beginning with mesitylene at 163°. The higher homologues include cumol, pseudocumol, durol, isodurol, cymol, isocymol, and doubtless other higher members. Larger proportions of these bodies appear in Ohio than in Pennsylvania petroleum and still larger proportions in Canadian crude oil. After the most thorough purification with nitric acid and fuming sulphuric acid the distillates from Ohio and Canadian petroleum have a slightly higher specific gravity than the corresponding bodies from Pennsylvania oil, and the hydrocarbons from Pennsylvania oil show a specific gravity slightly higher than that of the hydrocarbons synthetically prepared. Schorlemmer thought that these differences in specific gravity were due to slight differences in isomerism, but it is quite possible that these oils contain very small percentages of naphthenes, especially if those bodies are slowly attacked by reagents, as Markownikoff observed in products from Russian oil.

If Pennsylvania petroleum, as typical of this class of crude oils, is composed within the limits between 150° and 216° of the series C_nH_{2n+2}, the individual hydrocarbons should resemble those prepared by synthetic methods. Unfortunately the structure of the synthetic hydrocarbons has not been determined in all instances with desirable precision, although they have been obtained from different sources. Normal decane boiling at 173° has a specific gravity 0.7456 at 0°, somewhat lower than the decane I have separated from petroleum. The boiling point of the latter body is 173°.5, and the specific gravity at 20°, 0.7486. The decane found in petroleum boiling at 163° may be diisoamyl since its specific gravity after the removal of mesitylene is not very different from that of diisoamyl. Its boiling point is somewhat higher than the boiling point of diisoamyl assigned by Wurtz. Hendecane from petroleum agrees fairly well in its properties with normal hendecane prepared by Krafft from rautenol. The boiling point of petroleum dodecane is the same as that of normal dodecane from laurinic acid, although the specific gravity of the petroleum hydrocarbon is somewhat higher than the other.

Since nothing has been done toward defining the butanes in petroleum except the rather superficial examination of the most volatile distillates in the early days of the petroleum industry, these portions of the crude oil evidently invited further examination. The most volatile distillates of Pelouze and Cahours gave with chlorine a chlorbutyl boiling at 65°–70°, but nothing further was done toward identifying the hydrocarbon. Ronalds (*London Chem. Soc.*, 1865, p. 64) recognized a butane at 0°, but its form was not determined. Warren collected a distillate at 0°, and another at 8°–9°, which he inferred from analogy was a butane, but no further examination was made of these distillates. In our examination, after very prolonged distillation, using freezing mixtures for condensation, no distillate remained between 5° and 20°, thus excluding a butane at 8°–9°. At 0°, a large quantity of a hydrocarbon was obtained which gave a chlorbutane boiling at 67°–68°, the boiling point of isobutyl chloride. By decomposition of the chloride with alcoholic potassic acetate, an acetate was formed, and from the acetate an alcohol was obtained boiling at 107°–108°, which gave the percentages of carbon and hydrogen required for isobutyl alcohol. These facts, with the formation of isobutyl sulphide by treating the chloride with alcohol potassic sulphide, indicate that the hydrocarbon collected at 0° was isobutane, but they do not accord with the properties of butane and isobutane, the former of which, prepared by Frankland from ethyl iodide, boils at 0°, and the latter, prepared by Butlerow from tertiary butyl alcohol, boils at –17°. Petroleum butane was prepared several different times from the most volatile refinery distillates we could procure, and always with the same results (Mabery and Hudson, *Proc. Amer. Acad.*, xxxii, 101). In reviewing the octanes in petroleum, we found one boiling at 119°.5, confirming the statements of Warren, and another boiling at 124°–125°, but no distillate remained above 125°. From the results of my work recently published, and what I have now in progress, it can, I think, be stated with confidence that it is useless to attempt to separate the constituents of petroleum boiling above 220° by the ordinary process of distillation, and whatever results have been published concerning distillates obtained in this manner shed no light on the constituents of the crude oils. Of course this is cold sympathy for those who desire to know more of these higher portions, since there is only one method, fractional distillation, for such separations, and this method can only be applied without decomposition by excluding air and reducing the boiling points. To illustrate its tediousness, early in October, two assistants started a distillation of 125 liters of Pennsylvania crude oil applying a vacuum of above 150°. At present eight distillations have been made within 2° limits, up to 300° under 50 mm. Many repetitions within single degree fractions will be necessary to bring together the individual constituents.

The question is frequently asked whether paraffine is a normal constituent of the crude oil or is it a product of cracking. The answer is easy; paraffine is not obtained by cracking the crude oil, but it can itself be destroyed by cracking. If paraffine be contained in the crude oil it may be separated by distillation, provided cracking be not carried far enough to destroy it entirely. The presence of paraffine seems to be closely connected with the distinction mentioned between the series C_nH_{2n} and the series C_nH_{2n+2}. Higher distillates in vacuo of crude oils containing the series C_nH_{2n+2}, so far as I have observed, invariably deposit paraffine. Those oils consisting below 216° of the series C_nH_{2n} deposit no paraffine even when the highest distillates that can be collected are cooled to —20°. It may be interesting to apply this distinction to those oils that have been carefully studied. With reference to the appearance of paraffine in distillates, it should be mentioned that it is observed only in the absence of serious cracking, and that it is easy in vacuum distillation to recognize the point where cracking begins. In distilling 125 liters of Pennsylvania crude oil mentioned above for the purpose of separating the higher constituents, approximately forty liters of residue above 275° under 50 mm. became nearly solid from the amount of paraffine deposited. With the hope that more distillate could be obtained without decomposition, the semi-solid mass was put back into the still and again distilled under 50 mm. Approximately two liters were collected in three distillates, none of which deposited paraffine, and the residue, on cooling, had the consistency of a thick tar, with no indication of paraffine. Paraffine separates from the higher distillates of Berea grit petroleum, as well as from all specimens of Ohio and Canadian oils that I have examined; but none separated from South American petroleum, from Oregon petroleum, nor from Russian Baku oil.

Since I began the study of petroleum, twelve years ago, I have devoted considerable time to it, especially during the last seven years. Yet my results barely indicate the enormous field that awaits investigation in the examination of American petroleum. There is no field in industrial chemistry that offers greater inducements for fruitful results, both of scientific interest and practical advantage, than the study of the portions of petroleum with high boiling points. There are immeasurably greater inducements for the establishment of a petroleum laboratory for research on American petroleums than have led to the opening of similar laboratories abroad. Such a laboratory, established solely for research, with funds equivalent to twenty thousand dollars a year, and employing a corps of ten competent research chemists, in five years would add greatly to the honor of American research, and would establish the composition of American petroleum. The lines of work that I have in sight, and have started experimentally, would be sufficient to occupy the attention of such a body of workers at least during two years. I should be glad to resign a considerable portion of this work to such a laboratory, or to any other competent investigators.

Discussion.

Dr. Sadtler: I would like to say that there are one or two items referred to in Dr. Day's paper that may require a word. A paper appeared six months ago in a German journal by a gentleman named Heusler, in which he reported upon the action of aluminum chloride on the unsaturated series and perhaps on the aromatic series of hydrocarbons; and he claimed that by the heating of such mixtures with aluminum chloride (of course anhydrous aluminum chloride is meant), followed by distillation, carefully excluding moisture, he could readily and completely clear it by resinifying the unsaturated hydrocarbons and the aromatic hydrocarbons; any sulphur compounds could also be resinified; and he could then get by rectification absolutely pure hydrocarbons of the paraffin series.

That seemed to be a remarkable statement and one exciting attention; and a second article by the same author followed in the next number of the journal, in which he theorized a great deal upon Engler's menhaden oil products, and acknowledged having received from Engler by personal gift some portions of the distillates which he had obtained from these distillations of menhaden oil. He claimed that Engler's oils, when submitted to his treatment with aluminum chloride, had been purified and finally given the saturated hydrocarbons in rather small amounts. He then proceeded to theorize in what might hardly be called careful German style, but rather a free and unguarded kind of way, having a theory of his own supplementing that of Engler, his theory being that Engler's distillates in their original conditions were more like the bituminous shale oils than true petroleum ; and that it needed this after-treatment with the aluminum chloride to bring them at all in character to correspond to petroleum oil. He therefore believed—assuming Engler's theory of the animal origin of oils—that these animal remains had first of all been subjected to a distillation analogous to that with bituminous shales; and that a supplemental reaction with heat and contact with certain metallic chlorides—like the aluminum chloride, had transferred them into a secondary product, that is, the mixed petroleum or rock oil. The thing looked like a very fine solution of the question, but I have also noticed within the last six weeks two other articles published in the same journal, in which other authorities have claimed that this aluminum chloride reaction is a fallacy: that it does not by any means give a pure mixture of hydrocarbons belonging to the paraffin series and is absolutely worthless as a means of purification. It is stated that it cannot be carried out in the hands of any one except the gentleman who first published it. Prof. Day alludes to the possibility of sodium chloride playing an important part in the matter of producing these hydrocarbons of the Pennsylvania type from sulphur and oils similar to the Ohio type of oil. I doubt very much whether it is worth while to bring that in; because the thing seems to be discredited and that part, of course, will have to drop away.

There is something to be said in favor of the question of filtration that Mr. McGonigle speaks of. As to whether the sulphur could be eliminated by that or any sodium chloride reaction I doubt extremely; and therefore the theory which is presented by Dr. Day has several quite important breaks in it.

I need hardly make any comment upon the very interesting papers we have heard, first of Prof. Peckham and afterwards of Prof. Mabery. I have been acquainted for some time with Prof. Peckham's views with regard to liquid asphaltum and the way in which the change from petroleum may take place ; and there is an immense field, doubtless, there, to be opened and studied ; and then of course the whole thing is modified and very much complicated by the existence of what he calls hydrates of certain of these organic acids which are present; and then the presence of these pyridine bases also has some modifying effect.

With regard to the very full statement which we have had from Prof. Mabery, I need only say that he has accomplished an immense amount of work; and nobody except those who undertake fractional distillation will understand anything of the enormous difficulty that he has had in this work and the amount of labor he has put upon it; the results which he has already attained and published are, in my opinion, far beyond the combined work of the several investigators who have previously published results on Pennsylvania oil and American petroleum without specifying its origin, as in the case of the two or three European investigators.

Mr. Joseph Wharton: I should like to ask whether any gentleman here can throw any light as to the physical condition of natural gas at the low depth at which it is found; whether it exists as gas at the depth of 2000 to 3000 feet, or whether it is condensed into a liquid form at that depth. Is there any one here who has knowledge upon that point?

Prof. Mabery: It seems probable that the gas should be liquefied under the great pressure to which it is subjected. That the pressure is enormous we know. It depends somewhat, doubtless, upon the structure that exists in those lower strata. Some very interesting experiments have been made in studying those strata, and I think it is probable from what is known that natural gas has existed in the liquid form.

Mr. Wharton: Does any one know what the critical point of natural gas is?

Prof. Mabery: I should say it would depend largely on the critical point of marsh gas. Liquefaction of this gas takes place under 180 atmospheres at 11° degrees Centigrade.

Mr. Wharton: Has there been any experiment as to artificial liquefaction of natural gas?

Prof. Mabery: Yes; all those gases have been liquefied.

Prof. Peckham: The sulphur in petroleum may be derived from two different sources: where there is a very small percentage, a fraction of one per cent., it may be that the sulphur was a constituent of the original material from which the petroleum was produced; but where the sulphur content has arisen to several per cent., as is often the case in the more dense liquid and solid bitumens, I think the sulphur has been produced by a reaction between the material of the bitumen itself, and salts—sulphates—in natural waters. It seems hardly possible that from any source—any animal or vegetable source—that as much as seven per cent. of sulphur could become a constituent of a bitumen; and I have found that amount in natural bitumen.

Prof. Mabery: I am much interested in the results Prof. Sadtler has presented. Although Engler should receive much credit for obtaining petroleum products by the distillation of menhaden oil under pressure, it should be remembered that Warren and Storer demonstrated many years ago that a lime soap formed from menhaden oil gives by distillation the petroleum hydrocarbons. Now Prof. Sadtler has shown that the same products may be obtained by distillation of vegetable oils under atmospheric pressure. This overthrows the favorite theory of the German authorities based on Engler's results, that petroleum was formed exclusively from animal remains. The formation of petroleum hydrocarbons from vegetable oils is extremely interesting, and we should congratulate ourselves that it has been done so near the early home of the petroleum industry.

In the work of Prof. Peckham, I am especially interested just now, because I have been trying for several years to procure specimens of California oil, to ascertain whether it is composed of the series C_nH_{2n} or the series C_nH_{2n+2}. I was recently informed that ten gallons of this oil is on its way to my laboratory. I examined an oil from Oregon which I was told resembles the California oil, and from comparison with small samples of the California products in my possession, that seems to be the case. The Oregon oil, and another from South America, contain the series C_nH_{2n}, but none of the series C_nH_{2n+2}. Pennsylvania, Ohio and Canadian petroleum give paraffine in abundance. Oils containing the series C_nH_{2n} seem to give no paraffine, so far as I have examined them.

Prof. Peckham has a great field for investigation in the California oil, both on account of the large amount of nitrogen compounds, and the question as to what series of hydrocarbons constitutes the main body of the crude oil.

Prof. Peckham: In reference to this matter of paraffine in petroleum, there have been two classes of petroleum discovered in California; one produced in the neighborhood of San José, the other in the Santa Clara Valley of the South. The great bulk of California petroleum comes from that southern valley; and so far as I know no traces of paraffine have ever been obtained from any of it in any form—either what are known as the liquid nor the solid paraffines—not a particle of it has ever been obtained from any of the petroleum of the southern regions, but from that from the neighborhood of San José, scale paraffine has been obtained.

Prof. Mabery: Shale oil does not separate much paraffine; even in distillates above 350°.

PROCEEDINGS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY

HELD AT PHILADELPHIA FOR PROMOTING USEFUL KNOWLEDGE.

VOL. XXXVI. MAY, 1897. No. 155.

Stated Meeting, February 19, 1897.

The Treasurer, J. SERGEANT PRICE, in the Chair.

Present, 23 members.

Correspondence was submitted and letters of envoy and accessions to the library were reported.

A bronze medal, commemorative of its Sesqui-centennial, was presented by Princeton University, for which the thanks of the Society were given.

The following deaths of members were announced:

Dr. Henry Hartshorne, of Philadelphia, at Tokio, Japan, on February 10, 1897, æt. 73.

Hon. J. Randolph Tucker, of Lexington, Va., on February 13, 1897, æt. 73.

Prof. Henry D. Gregory, of Philadelphia, on February 14, 1897, æt. 77.

The stated business of the meeting being the election of members, the nominations were spoken to, and the ballots cast, Secretaries Hays and Prime acting as Tellers.

Prof. Cope presented a "Communication on Some Paleozoic Vertebrata from the Middle States."

A communication was laid before the Society, consisting of a sketch of an act to be presented to the Legislature of Pennsylvania setting apart three areas of 40,000 acres each on the water sheds of the Delaware, Susquehanna, and Ohio, for a State Forestry Reservation.

Judge Sulzberger moved that the American Philosophical Society heartily approves of the purpose to secure State Forestry Reservations for the Commonwealth and recommends to the Legislature the passage of the measures necessary to carry this purpose into effect. Adopted.

The Tellers reported that the following nominees had been elected to membership:

2302. Morris Jastrow, Philadelphia.
2303. Ferdinand J. Dreer, Philadelphia.
2304. William H. Furness, 3d, M.D., Wallingford, Pa.
2305. Edwin Grant Conklin, Ph.D., Philadelphia.
2306. Horace Howard Furness, Jr., Philadelphia.
2307. H. M. Hiller, M.D., Philadelphia.
2308. John Sartain, Philadelphia.
2309. Henry Trimble, St. David's, Pa.
2310. George W. Biddle, Philadelphia.
2311. Alexander C. Abbott, M.D., Philadelphia.

The meeting was then adjourned by the presiding officer.

Stated Meeting, March 5, 1897.

The Vice-President, Dr. Pepper, in the Chair.

Present, 12 members.

Prof. Trimble and Dr. Abbott, newly elected members, were presented to the Chair, and took their seats.

Acknowledgments of election to membership were received from Prof. Morris Jastrow, Jr., Mr. Ferdinand J. Dreer, Prof. Edwin Grant Conklin, Dr. H. M. Hiller, Prof. Henry Trimble, Mr. George W. Biddle and Dr. Alexander C. Abbott.

Donations to the Library were reported.

Prof. Arthur W. Goodspeed exhibited some recent radiographs, and made a comparison of them with the work of a year ago.

Dr. Pepper, Mr. Ingham and Dr. Hays participated in the discussion following Prof. Goodspeed's remarks.

Stated Meeting, March 19, 1897.

Vice-President, Dr. PEPPER, in the Chair.

Present, 12 members.

Acknowledgments of election to membership were received from Mr. John Sartain, Dr. W. H. Furness, 3d, Mr. H. H. Furness, Jr.

The announcement of the decease of the following members was made and obituary notices of them were ordered to be prepared:

Mr. Arthur Biddle, at Atlantic City, on March 8, æt. 44.

Prof. James J. Sylvester, at London, Eng., on March 15, æt. 83.

Prof. George Stuart, at Philadelphia, on March 16, æt. 66.

Donations to the Library and Cabinet were announced, and in connection with the latter, Dr. Morris moved "That Mr. Patterson's deposit of the Illustrated Catalogue of the Peale Collection of the Stone Age to be returned on his demand, be accepted, and that it be placed in charge of the Curators." Adopted.

Prof. Edwin J. Houston and Dr. A. E. Kennelly read a paper entitled "The Insulating Medium surrounding a Conductor, the Real Path of its Current."

Dr. Hays moved that a Committee of five members be appointed to consider and report upon the advisability of the Society publishing a Calendar of the Franklin Correspondence in its possession, and if found advisable, to recommend a plan for such a calendar and its publication. Also to consider and report on the historic relation to the original document of the manuscript copy of the Declaration of Independence sent by Jefferson to Richard Henry Lee, and now in the possession of this Society, and whether its historic importance renders desirable its reproduction by the Society. Adopted.

Dr. Pepper, Judge Mitchell, Mr. Carson, Mr. Stone and Dr. Bache were appointed the committee under the above resolution.

THE INSULATING MEDIUM SURROUNDING A CONDUCTOR THE REAL PATH OF ITS CURRENT.

BY EDWIN J. HOUSTON, PH.D., AND A. E. KENNELLY, SC.D.

(Read March 19, 1897.)

Up to the commencement of the present century our knowledge of electricity and its action was almost entirely confined to the phenomena of electric charges and their dissipation by discharge. The conception of an electric current as a steady condition of discharge had not then been clearly apprehended. It was observed that dissimilar bodies, when placed in contact with, or rubbed against, each other, manifested electric excitation. It was assumed that the electric charges thus acquired resided upon the exterior surfaces of the charged bodies, and that charged bodies evidenced mutual electric attractions and repulsions at a distance. The idea of action at a distance was, therefore, inseparably connected with early conceptions of electricity and electrical phenomena. Action at a distance was explained by some on the hypothesis that an electrified body emitted an invisible electric effluvium which acted upon electrified bodies in its vicinity. It was observed that electric charges were transmitted through certain bodies called conductors, and failed to be transmitted through other bodies called non-conductors or insulators. In a similar manner the phenomena of magnetism, as developed up to the commencement of the present century, pointed to the seeming attraction and repulsion of magnetic poles. According to the views then existing, a magnet was a skeleton of iron or steel for supporting two opposite poles at its extremities. These poles manifested peculiar properties to which the intervening skeleton was considered as merely subordinate. This magnetic action at a distance, by which the magnetic poles of the earth were assumed to direct the compass needle, was supposed by some to be effected through the medium of a magnetic effluvium emitted from the poles of the magnet. Up to the commencement of the present century, therefore, electric and magnetic phenomena were studied apart, and each was accredited with the possibility of action at a distance, except in so far as some physicists endeavored to explain such action by the intervention of material electric and magnetic effluvia. About the commencement of the present century, the discovery of the voltaic pile brought to the notice of electricians the development of an electric current, or a steadily maintained discharge. The phenomena produced by the electric current were apparently so different from those produced by electric charges that they were at first believed to be essentially distinct. The electric current could only be produced when a complete conducting path or circuit was provided, any breach of continuity in the conducting circuit immediately interrupting the current flow. Consequently, it appeared that the electric current passed through the conductor, usually a metallic wire, in a manner somewhat similar to that in which a liquid flows through a pipe. Moreover, the electric current was apparently restricted to the conductor, and could not pass through the insulating medium surrounding it.

In 1820, not long after the discovery of the voltaic pile, Oersted announced the first known connection between electricity and magnetism. Using the usual language, when a wire, through which an electric current is flowing, is brought into the neighborhood of a suspended magnetic needle, the poles of the needle are attracted and repelled in a manner depending upon the direction of the current and its position relatively to the needle. Here an electric current apparently acted at a distance on the needle; for, in the insulating medium, usually the air, in which the magnet was suspended, no electric current could flow, and yet the magnet's poles could be acted upon at a very considerable distance from the wire carrying the electric current.

Up to the middle of the present century, therefore, the phenomena of electricity, magnetism and electromagnetic action, suggested both action at a distance, and that electric currents pass solely through the mass of a conducting wire independently of the external insulating medium. It is true that the idea of action at a distance was regarded as illogical, and as contrary to the fundamental principles of dynamics, ever since the days of Newton, but despite this unwillingness of physicists, the old notions of actions at a distance continued to be thus passively employed and promulgated, and, even to-day, they still permeate scientific literature. Another reason for the retention of the recognizedly erroneous ideas of action at a distance is to be found in the fact that, up to the middle of this century, all the mathematical processes adopted for dealing with the phenomena of electricity, magnetism and electromagnetic action, tacitly assumed the principles of action at a distance just as the mathematical processes of astronomy at the present time tacitly assume the same law, without pretending to explain the mechanism by which such action may be conveyed. Consequently, it was only too easy for students to imbibe, with the mathematical ideas for studying quantitative electromagnetic facts, the fundamental hypothesis of action at a distance upon which this idea was based. Thus the mechanical forces existing between charged electrified bodies, between magnet poles, between electric currents, or between electric currents and magnets, were all referred to the mutual actions of elementary portions of imaginary electric or magnetic substances, each of which exerted an influence proportional to its quantity, and inversely proportional to the square of its distance from the element acted on. About the middle of the present century, Faraday first paved the way for a change in our views on these questions. He suggested the theory that an electrified body or a magnet did not emit any material effluvium, but exerted an influence on the invisible medium in its vicinity; namely, the universal ether; that this influence was of the nature of a stress, and that the ether surrounding an electrified or magnetized substance was in some manner strained along certain directions which he called lines of force. Consequently, an electrified body produced lines of electric force along which the ether was strained, while a magnetized body similarly produced lines of magnetic force along which the ether was strained, but in a manner different from electric strain. It was this strained ether that connected the electrified or magnetized bodies with bodies in their neighborhood, and permitted attraction and repulsion to be set up between them without necessitating any action at a distance.

Clerk Maxwell developed the ideas of ether strains and stresses mathematically. While retaining the original methods of quantitatively determining the mechanical actions between electric and magnetic bodies, by summing up the effects of all the elements of those bodies on each other, in reference to the inverse squares of the distances, he developed, at considerable length, the action of the intervening medium, and showed how the strain in such medium could produce the mechanical effects observed. In the treatment of this subject he noticed that a disturbance of the electric or magnetic condition of the ether was controlled by a formula similar to that which controls a disturbance in an elastic solid. He was, therefore, led to believe that electromagnetic disturbances in the ether were propagated in all directions like disturbances in an elastic solid, and were, therefore, transmitted in waves. Maxwell, therefore, was the discoverer of the probability of electromagnetic waves in ether. He also suggested that light might be a purely electromagnetic phenomenon of very high frequency, and adduced experimental evidence in favor of this belief. The actual existence of these electromagnetic waves has since been abundantly demonstrated by Hertz and many others. Though invisible to the unaided eye, electromagnetic waves can be traced by the aid of sensitive electromagnetic apparatus constituting what has not been inaptly styled the electric eye.

As the result of both the experimental and mathematical work of the latter half of the present century, especially that of Mr. Oliver Heaviside, it is now believed that electric currents are transmitted as electric waves through the ether surrounding a conductor, being guided by the conductor, but not transmitted through it.

Notwithstanding the fact that the more modern views have been in existence for upwards of thirty years; that their truth is practically undisputed, and that, on the contrary, within the last ten years, strong experimental evidence has been adduced in their behalf, yet both the old phraseology and the old methods of treatment are still almost universally employed even in the modern text-books of the day.

In view of the preceding facts, the authors consider that a brief description of the manner in which an electric current is now believed to be transmitted, may aid in disseminating the more modern views.

All electric, magnetic or electromagnetic phenomena are now believed to be referable to two conditions of stress in the ether, one of which is called *electric flux*, and the other, *magnetic flux*. The exact nature of both is unknown. Though invisible, the presence of each may be manifested in a variety of ways. So intimately are the electric and magnetic fluxes correlated, that any disturbance in one immediately calls the other into existence. Electric flux exists between two electric charges. Thus, a positively charged sphere, situated at rest in a room, radiates streams of electric flux, towards all parts of the room, along lines called *stream lines*, which may be readily mapped out. The ether is strained or disturbed in some manner along these stream lines. So long as the charge on the insulated body remains at rest, electric flux will permeate the air and ether in the room, but there will be no magnetic flux present, except that due to the earth's magnetism. As soon, however, as any motion occurs in an electric flux, either by moving the charge on the body, or by causing it to increase or decrease in density, the disturbance in electric flux temporarily produces a magnetic flux; and, generally speaking, any variation or motion of electric flux produces magnetic flux.

A permanent magnet produces magnetic flux, both in its substance and in the space surrounding it. So long as the distribution of magnetic flux remains quiescent, no electric flux is produced. As soon, however, as any change takes place in the magnetic flux, either by bodily moving the magnet, or by weakening or strengthening the magnet, electric flux is temporarily produced. Generally, any variation or motion of magnetic flux produces electric flux.

Magnetic flux is always circuital, or is distributed in stream lines which form closed curves, or have reëntrant paths. Electric flux, when established between opposite electric charges, is not circuital, but terminates at one end in one charge, and at the other end in the opposite charge. When, however, electric flux is established by magnetic disturbances in a space free from conductors, it is circuital, like magnetic flux.

Both electric and magnetic flux possess both direction and polarity; that is to say, each is developed along definite stream lines, and each possesses different properties up and down such stream lines. An analogy is presented mechanically in a stream of water. Water in a river flows in stream lines, and is directed in its motion down stream. In the case of electric flux the polarity is manifested by what are called positive and negative charges, these charges being developed where the electric flux terminates. In the case of magnetic flux the polarity is manifested by what is called north-seeking poles and south-seeking poles. These poles are developed where the magnetic flux terminates on the magnet. For this reason electric flux is conventionally assumed to leave a positive charge and, to terminate, on arrival at a conductor, at a corresponding negative charge. This, while being a purely arbitrary assumption, is, nevertheless, advantageous in fixing ideas. Similarly, magnetic flux is assumed to issue from a magnet at its north-seeking pole and to reënter it at its south-seeking pole. This assumption is also purely arbitrary.

Both electric and magnetic fluxes contain energy. Work must be charged on the flux to establish it, and this work is liberated when the flux disappears. The energy in the ether varies as the square of the flux density, so that if we crowd uniformly twice as much flux through a given area of cross-section, we quadruple the amount of energy which resides in that portion of space per cubic inch, or per cubic centimetre.

The electric transmission of power consists in transferring electric and magnetic flux to a distance and allowing these fluxes to be expended in liberating, at the receiving end of the line, the energy they contain. An electric generator is a machine for producing electric flux and thus transferring electric energy to the ether. This electric flux, or energized condition of the ether, is transferred to a distant point along wires, the ether being deprived of its energy at the receiving end of the line. The electric flux is there absorbed, and the work which was expended by the generator is recovered to a greater or less extent.

The electric flux is transmitted from the generator to the receiver, through an insulating medium, being guided on its passage by a pair of conductors, extending all the way from the generator to the receiver. Such a pair of conductors, with the associated insulating medium between them, is called an *electric circuit*. The curious fact exists that while the old conception of an electric circuit held that the electric current passed through the conductors, and was retained in position on those conductors by reason of the insulating medium surrounding them, the modern view holds, on the contrary, that the electric current flows through the insulating medium and is held in position, or guided to its destination, by the two conductors. In other words, the modern theory completely reverses the relative functions of the insulator and the conductors in the old theory.

There are three standard types of pairs of conductors, and their associated, intervening, insulating medium; viz.,

1. An aërial conductor, such as a telegraph wire, supported sensibly parallel to the surface of the ground. Here the wire forms one conductor, the ground the other conductor, while the ether associated with the air between them is the medium through which the electric current flows.

2. Subterranean or submarine conductors separated from the surrounding conducting earth or water by a uniform layer or coating of insulating material. Here one conductor is formed by the

interior wire, while the other conductor is the sheath of metal, liquid or ground, and the medium through which the electric current flows is the ether in the insulating coating of rubber, gutta-percha, paper, etc., with which the interior conductor is invested.

3. A pair of overhead wires supported sensibly parallel to each other, on suitable insulating supports; as, for example, a pair of telephone or electric-light conductors. Here the two wires are the conductors, and the medium through which the electric current flows is the ether in the air between them.

When an electric source is connected to any such pair of conductors, an electric flux is established in the insulator between them; or, more correctly speaking, in the ether permeating the insulator. The density of the electric flux, or the quantity of flux per normal square centimetre, will depend upon the nature of the insulator, on its dimensions, and on the electric pressure or voltage of the source. An increase of voltage is attended by a proportional increase in the density of the electric flux; while an increase in the thickness of the layer of insulating material between the conductors diminishes the density. Figs. 1, 2, 3, are diagrams of the distribution of electric flux for the three types of circuit mentioned.

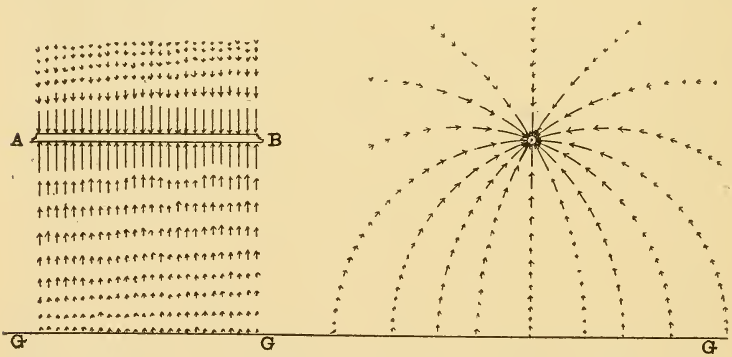


FIG. 1.—Electric Flux Surrounding an Aërial Wire with Ground-Return Circuit.

In Fig. 1, AB, represents the aërial wire, and GG, the ground. The flux stream-lines are represented on the right-hand side in a plane perpendicular to the wire. These stream lines are arcs of circles, on the supposition that the ground, GG, is conducting, and has a level surface, such as might be presented by the surface of water in a lake. On the left-hand side the flux is represented as being distributed in straight lines; *i. e.*, in sections of planes, perpendicular to the wire and to the ground. The wire being negatively charged, by convention the flux streams converge towards it.

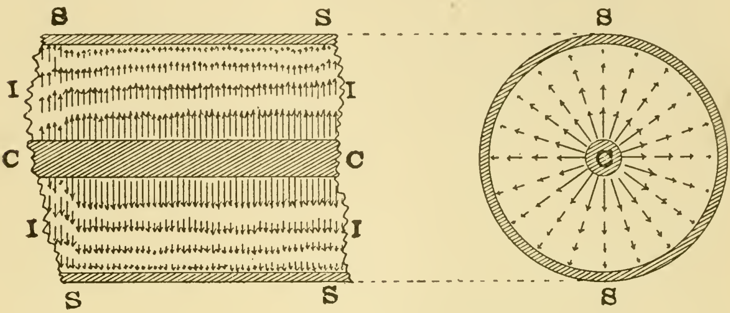


FIG. 2.—Electric Flux Permeating Insulator of Cable.

In Fig. 2, CC, is an insulated conductor, usually of copper, separated from the conducting sheath SSSS, which may be of lead or other metal, by the cylindrical insulating jacket IIII. Here the flux is represented as emerging from the wire which is, therefore, regarded as positively charged. The density of the flux is greatest in the vicinity of the interior conductor, and diminishes uniformly as we proceed towards the sheath. This is represented diagrammatically by the length of the flux arrows. On the left-hand side the flux is seen to be distributed in planes perpendicular to the length of the cable.

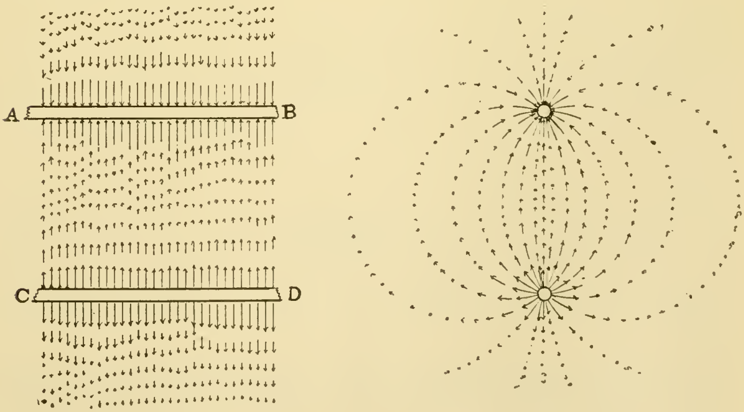
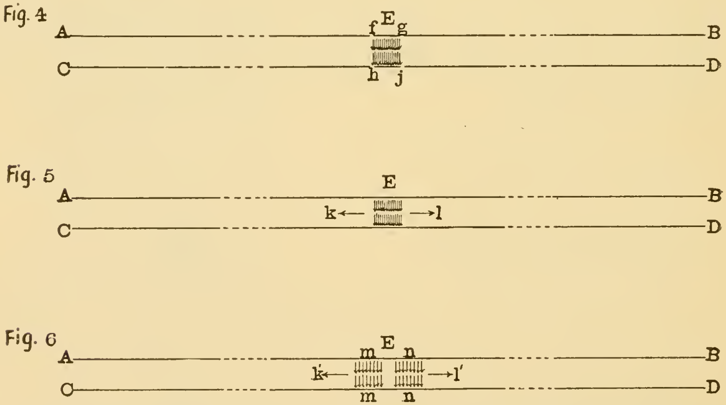


FIG. 3.—Electric Flux Permeating Insulator between Two Parallel Wires.

Fig. 3, represents two parallel wires, AB and CD, the latter positively and the former negatively charged. Here the flux issues from the wire CD, and converges upon the wire AB, in curves, which are all arcs of circles. The flux density is greatest in the neighborhood of each wire and least in the intermediate portions. On the left-hand side, the longitudinal section shows that the flux is distributed uniformly in planes perpendicular to the two wires.

The electric flux, which thus permeates the insulating medium, persists as long as the insulation is maintained, even in the absence of the original electric source. Thus, if a pair of wires be perfectly insulated from each other, and are charged as represented in Fig. 3, by connection to an electric source; then, so far as is known, the electric flux, which will be developed between them in the insulating medium, will be indefinitely maintained, although in practice there is always sufficient leakage to permit the charge to gradually disappear.

In order to study the electric transmission of power over a circuit, we may suppose that a pair of perfectly conducting wires exists extending between two cities. These conductors may be, say, of the third type; *i. e.*, may consist of a pair of parallel wires supported in air. Let AB and CD, Fig. 4, represent such a pair of conductors



FIGS. 4–6.—Movement of Electric Flux in Circuit of Perfect Conduction and Insulation.

between the terminal stations AC, on the left hand, and BD, on the right. At the middle of the line E, we may suppose that suitable short lengths of each of the two wires; namely, fg and hj, each one metre long, are insulated from the rest of the system, and electrically charged by a momentary connection to a dynamo or other suitable source, to a pressure of say, 1000 volts. An electric flux will thus be established between the two short lengths of wire of the type represented in Fig. 3, and shown in Fig. 4, by the arrows; fg, being positive, and hj, negative. Strictly speaking, the flux disturbance would not remain in parallel planes at the ends of the short lengths, but would bulge outwards considerably, from the ends; but this peculiarity is of no consequence to what follows, and we may, therefore, suppose that the simpler geometrical distribution is preserved. If the metre lengths at E, be perfectly insulated from each other, the block of electric flux resident in the ether between them would be indefinitely maintained at 1000 volts pressure.

Suppose, however, that at some instant of time the discontinuities existing between the metre lengths of the conductors and the rest of the system are suddenly bridged over. In other words, the metre-lengths are connected electrically at both ends to the rest of the circuit. Then instantly the flux tends to rush towards the ends of the circuit as represented by the arrows k and l, in Fig. 5. The metre block of flux instantly subdivides into two metre blocks, each under 500 volts pressure, and each with half the original density and, therefore, one-quarter of the original energy. At the same time, the moment that the flux commences to run, a magnetic flux distribution is brought into existence; for, as we have already mentioned, a motion of electric flux can never occur without producing magnetic flux. While then the metre block of Fig. 5, divides into two separate metre blocks, moving in opposite directions, as in Fig. 6, each block becomes invested with magnetic flux in the manner represented in Fig. 7. Here the curves of magnetic flux distribution, indicated by arrows, are circles eccentric to the wires. One-half the energy of each moving block is electric and is resident in the electric flux, and one-half is magnetic and is resident in the magnetic flux. It will be observed that the magnetic flux is so directed as to pass through the loop formed by the two wires, in planes perpendicular to the wires. Moreover, the curves of magnetic flux stream-lines are all perpendicular to the curves of electric flux stream-lines, which, already shown in Fig. 2, are here represented by dotted lines. The magnetic flux at each point is due to the movement of the electric flux through the ether at that point, and is not due, as the old theory supposed, to an assumed current in the wire. The passage of the electric flux over the wires constitutes a momentary electric current, which in this case would have a strength of roughly two amperes. The velocity with which the flux blocks move in Fig. 6, is the velocity of light in air; approximately, 300,000 kilometres per second. If the distance from E, to the ends of the wires is exactly 300 kilometres each way, the metre blocks of

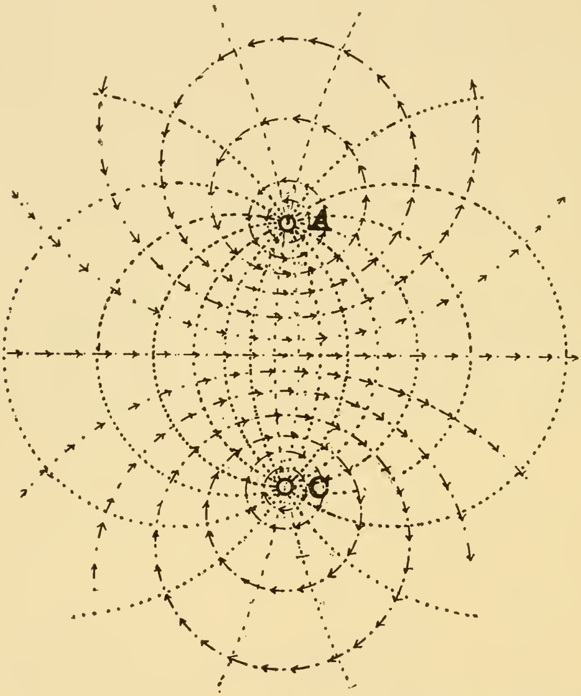
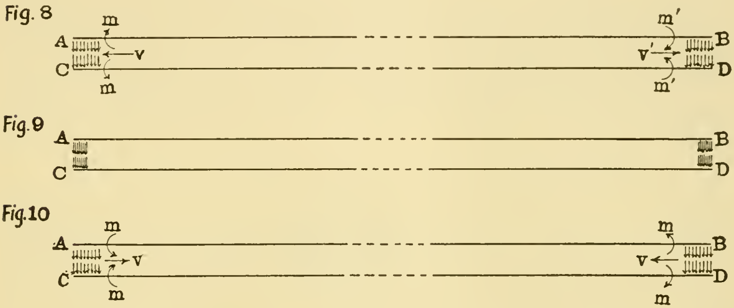


FIG. 7.—Magnetic Flux Accompanying Moving Electric Flux between Two Parallel Wires.

flux will traverse this distance in $\frac{1}{1000}$th of a second. The metre blocks will, therefore, pass by any particular point on the line in $\frac{1}{300,000,000}$th of a second, and the electric current, which this flux rush constitutes, would, therefore, have this duration at any particular point.

Fig. 8, represents the metre blocks of flux in the act of arriving at the termini of the line. The two conductors are open-circuited, or insulated, at both ends. The arrows v and v′, represent the direction in which the blocks have arrived, and the curved arrows mm, and m′m′, represent the direction of magnetic flux which has been generated by the movement of each block, and which has been carried bodily along with the moving blocks. If the original metre block of flux in Fig. 4, represents an amount of energy resident in electric flux, amounting to say 1000 ergs, then each of the two metre blocks into which this is divided, assuming no dissipation of energy, carries with it 500 ergs, 250 in magnetic flux and 250 in electric flux.

Fig. 8

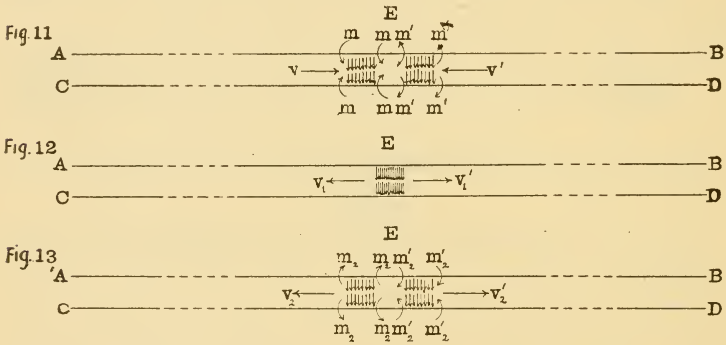


FIGS. 8–10.—Reflected Movement of Electric Flux in Circuit of Perfect Conduction and Insulation.

On arrival at the termini, the flux is compressed into a half metre at each end, as represented in Fig. 9. The density of electric flux is doubled, as represented by the closeness of the arrows. At the same time the magnetic flux vanishes, while the pressure rises momentarily from 500 to 1000 volts. There is, therefore, half the volume of flux with twice the density; and, therefore, four times the voluminal electric energy, but no magnetic energy. Consequently, there remains 500 ergs of purely electric energy in each block.

Fig. 10, represents the conditions of affairs immediately afterwards. Here the blocks expand again into metre lengths and are reflected from the termini, or move back towards the centre of the line. The magnetic flux reappears, but in the reversed direction, as shown by the curved arrows. The electric flux retains its original direction from the upper to the lower wire, and the pressure has fallen from 1000 to 500 volts as before. The current represented by the flux rush is, therefore, reversed in direction, since the magnetic flux, by which it is measured, is reversed, but the electric potential difference, as measured by the density of electric flux, remains unaltered. The two metre blocks now rush towards the centre of the line with the speed of light. They may be considered as solitary waves of light, that is to say, disturbances traveling with the velocity of light waves, but not periodic, and leaving the medium quiescent the moment they pass by.

After the lapse of another $\frac{1}{1000}$th of a second, the two metre blocks, which will again arrive at E, the middle of the line, as shown in Fig. 11, where the two arrows v and v′, indicate that the blocks are about to collide. The curved arrows show that the magnetic flux is oppositely directed in the two blocks, those on the left-hand side at mm, being directed into the loop, as seen by the observer, while those on the right-hand side at m′m′, being directed out of the loop.

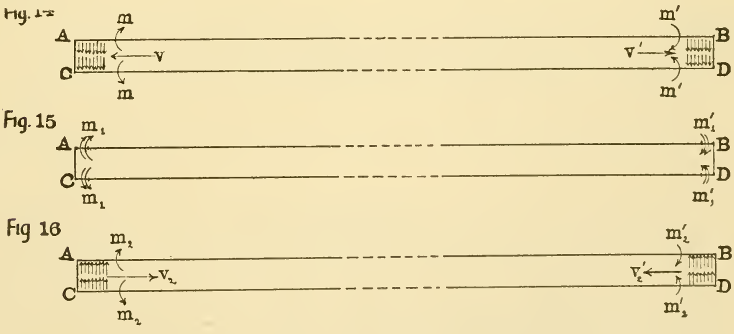


FIGS. 11–13.—Collision of Electric Flux Waves in Circuit of Perfect Conduction and Insulation.

In Fig. 12, the metre blocks are represented as having collided; they have merged together and mutually annulled each other's magnetic flux. Consequently, there is no magnetic energy. On the other hand, the density of electric flux being doubled, there will be four times the electric energy per cubic centimetre. Consequently, there are 1000 ergs of electric energy in the single metre block at 1000 volts pressure, just as in the original condition before the start, in Fig. 5. The two blocks, however, pass completely through each other, appearing on the opposite sides.

Fig. 13, represents this condition of affairs. Here the two blocks have passed completely through each other and once more rush out with the velocity of light towards the ends of the conductors, which they will reach in the $\frac{1}{1000}$th of a second. This process of meeting in the centre, separating, reaching the ends, and being reflected therefrom, will repeat itself indefinitely in cycles which take $\frac{4}{1000}$th of a second to complete, the current direction reversing at each reflection from the ends. In this case of perpetual motion, we have assumed that there is no dissipation of electromagnetic energy, there being no leakage between the two conductors, and perfect conduction in the two wires.

We have hitherto assumed that the two wires AB and CD, were open-circuited, that is insulated from each other at their termini. We now suppose that they are short-circuited; that is directly connected at the termini. Let the metre block of flux be started from E, the centre of the line, as in Fig. 5. Then, in $\frac{1}{1000}$th of a second, the two metre blocks, into which the original block divides, will rush over the intervening 300 kilometres, and will reach the ends of the line as shown in Fig. 14, the arrows v and v′, indicating the direction in which the blocks have arrived, and the curved arrows representing the direction of accompanying magnetic flux. In this case, instead of the electric density being doubled, the electric flux vanishes completely as soon as the magnetic flux is compressed into half a metre of length. The magnetic flux is, however, doubled in density, as represented by the doubled curved arrows of Fig. 15. Here the energy is all magnetic, and each half-metre block of magnetic flux at the ends of the line contains 500 ergs of energy.



FIGS. 14–16.—Reflected Movement of Electric Flux in Circuit of Perfect Conduction and Insulation, Short-Circuited at Termini.

Fig. 16, represents the condition of affairs the moment after the disappearance of electric flux. Here the electric flux has reappeared in the form of the two metre blocks, which take their departure towards the centre of the line, but now it will be observed, by the direction of the flux arrows, that the electric flux is reversed in direction. Consequently, the lower wire has become positive and the upper wire negative; or, the 500 volts difference of potential between the wires is reversed in direction by reflection from the short circuits at the termini. The magnetic flux possesses its original direction as shown by the curved arrows. Consequently, the momentary current, which is constituted at any point along the line by the flux rush past it, does not change direction when the pulse comes back reflected.

The two reflected metre flux-blocks rush with the speed of light towards the centre of the line. The condition of affairs just before they meet is represented in Fig. 17. The magnetic flux is oppositely directed in the two blocks. Consequently, when the two blocks merge, as shown in Fig. 18, the magnetic flux is annulled, but the electric density is doubled. We have, therefore, in Fig. 18, 1000 ergs of energy in electric flux, situated in a metre block, but with the opposite direction of potential to that which exists in the original state of Figs. 4 and 5.

Fig. 17

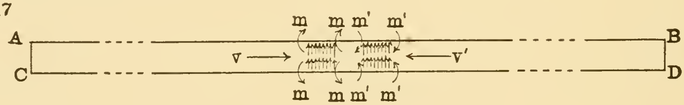
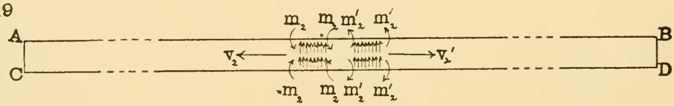


Fig. 18

Fig. 19



FIGS. 17–19.—Collision of Reflected Electric Flux Waves in Circuit of Perfect Conduction and Insulation Short-Circuited at Termini.

The two metre blocks then separate out by passing through each other as shown in Fig. 19, where the two blocks are seen to be withdrawing from each other with the speed of light. They again rush to the termini of the line, where they undergo reflection with reversal of electric flux and persistence of magnetic flux. This condition of reflection and collision would continue forever, under the conditions assumed.

We have hitherto assumed that the insulator insulated perfectly and the conductor conducted perfectly. Neither of these two conditions is attained in practice. We will first assume that there is imperfect insulation in the insulator, with perfect conduction in the wires. For convenience, we may change the type of circuit to the second; namely, a cable composed of a central wire and annular external conducting sheath. This is represented in Fig. 20,

Fig 20

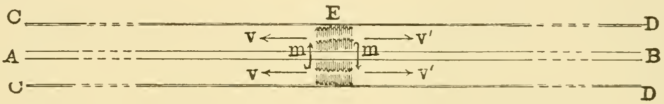



Fig. 21

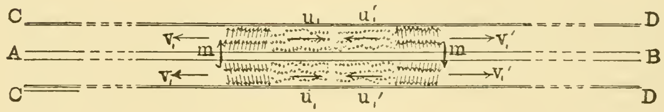
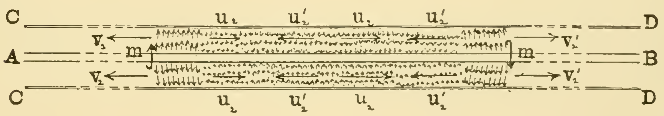


Fig. 22



FIGS. 20–22.—Movement of Electric Flux in Cable of Imperfect Insulation and Perfect Conduction.

where AB, is the central conductor and CD, CD, the external conducting sheath. Let us suppose that a metre block of flux, at 1000 volts, is, as before, called into existence, and released from the centre of the line. The flux block immediately starts with the velocity of light in the ether of that particular insulator, which may be, perhaps, 200,000 kilometers per second, instead of 300,000 kilometers per second, as in free ether. The block, as before, subdivides into two metre blocks, each with half the density and each with its attendant magnetic flux, as represented by the straight and curved arrows of Fig. 21. Instead, however, of pursuing their paths as sharply defined blocks, the two blocks are subjected to attenuation by leaving stragglers or remnants along the road, since the insulator is somewhat leaky. That is to say, the path through which they pass is strewed with reflected or oppositely directed electric flux, of reduced density, which immediately turns around and moves back towards the centre of the line with the velocity of light in that medium. Consequently, the two metre blocks undergo a process of decay; their density is diminished; their energy is dissipated in the insulator as heat, and in supplying the straggling reversed fluxes; and the distribution, instead of being in planes perpendicular to the cable, is bent backwards in a manner which is exaggerated in Fig. 21. In fact the flux behaves as though it got entangled in the insulator instead of moving freely through it, and by reason of the entanglement, a number of shreds or straggling particles are detached from the advancing main body. If the leakage be sufficiently great, the blocks of flux may be completely dissipated before they arrive at the termini of the line, the degree of attenuation depending entirely upon the amount of leakage.

Fig. 22, represents the condition of affairs at a later stage of the first outward movement of the flux blocks. Here v_2 v'_2, represent the movement of the heads of the columns; u_2 and u'_2, represent the backward movement of the stream of stragglers thrown off by the heads in the course of their motion. Consequently, the entire field between the two separating heads is filled with a confused and straggling mass of attenuated flux, and a very complex state of affairs is reached. The original blocks are entirely absorbed after they have traveled a greater or less distance.

We may next assume that the insulator insulates perfectly, but that the wires do not conduct perfectly. This is a condition which is very nearly represented in many practical cases. In Fig. 23, the metre block of flux starts from the centre as before. The interior conductor being positively, and the sheath negatively, electrified. The curved arrows represent the direction of accompanying magnetic flux, produced as soon as the motion takes place. Here the imperfect conduction of the wire sets up a series of straggling reflections of electric flux, in the same direcion, however, as that in the moving blocks, instead of the opposite direction, as in Figs. 21 and 22. The electric flux is bent from the perpendicular in the direction of motion, as represented in exaggeration at Fig. 24. Consequently, the metre blocks are subjected to a process of attenuation or decay, by throwing off attenuated electric flux as they advance, the straggling flux so thrown off immediately commencing to rush backwards with the velocity of light in the medium as represented by the arrows u_1 u'_1. The metre blocks, therefore, lose definition as they advance, becoming weaker and weaker, the energy being lost into the conductor and into straggling flux. If the wires conduct sufficiently imperfectly, the two metre blocks may be completely absorbed before they reach the terminals of the line, the degree of attenuation depending entirely upon the degree of imperfection in conducting power, for a given electric cable; *i. e.*, a given geometrical distribution of insulating medium. The fact of imperfect conduction, may be represented roughly by supposing that the flux, instead of slipping freely along the surface of the conductor, becomes entangled in the surface of the same, and friction between the base of the moving flux and the surface of the wire detaches some of the flux and leaves the detritus in the pathway.

Fig. 23

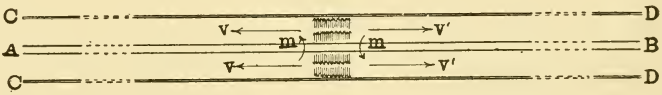


Fig. 24

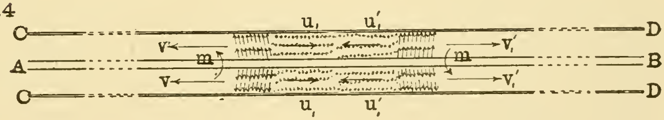
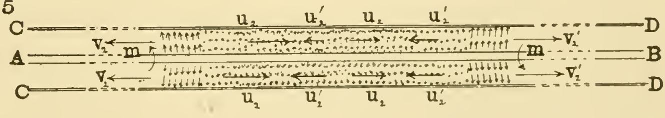


Fig 25



FIGS. 23–25.—Movement of Electric Flux in Cable of Perfect Insulation and Imperfect Conduction.

Fig. 25, represents the condition of attenuation at a later stage.

Here the original metre blocks have diminished considerably in density, and in their stock of energy, their motion being indicated by the arrows v_2 and v'_2. u_2 and u'_2, are arrows representing the motion of the straggling flux, or *tails*, as they have been called, thrown off by the advancing blocks. After a certain distance has been traversed by these blocks they become completely absorbed and the tails only remain, the subsequent motion being very complex.

All the best electric conductors with which we are acquainted; namely, the metals, conduct imperfectly at the temperatures at which they exist on the earth. It has been shown that pure copper would apparently conduct to perfection, or have no electric resistance, at the temperature of absolute zero, or — 273° C. It is possible that some means may eventually be found to artificially produce in copper, at ordinary temperatures, the electric conducting power it possesses at or near the absolute zero of temperature, but at the present time we have to content ourselves with the comparatively imperfect conducting power of copper, which is practically the best electric conductor available. Consequently, we cannot attain in practice to the distortionless transmission of electro-magnetic waves such as represented in Figs. 4 to 19.

It is, however, possible to so unite imperfect insulation with imperfect conduction; *i. e.*, leakage with conductor-resistance, as to cause the tailings due to leakage to exactly annul the tailings due to conductor resistance; for, the comparison of Figs. 20, 21 and 22, with Figs. 23, 24 and 25, will show that these tailings are oppositely directed as regards electric flux, the tailings from leakage being reversed, and the tailings from conductor resistance being similarly directed, to electric flux in the main blocks. A circuit in which the leakage and conductor resistance are so balanced as to leave no tailings, is called a *distortionless circuit*, and no other means of obtaining a distortionless circuit is known at the present time. Although such a circuit is distortionless, since no tailings are left, as the blocks of flux move on without leaving stragglers, yet energy is expended both into the insulator and into the conductor, and, consequently, the fluxes diminish in density and attenuation goes on. This is represented in Fig. 26. Here the metre block of flux is started from the centre of the line as before, the directions being indicated by the arrows. In Fig. 27, the electric flux is seen to have a double curvature, being partly bent outwards and partly bent inwards. Energy is being dissipated sideways into the insulator, and sideways into the conductor, as the blocks move on. Consequently, the electric density and the accompanying magnetic density are diminishing, but no straggling electric or magnetic flux is left to mark the passage of the blocks. If the original stock of energy was 1000 ergs, the energy which may reside in the two blocks, when they reach the ends of the line, may be, perhaps, only 100 ergs, depending entirely upon the amount of electric resistance in the conductor, and the corresponding amount of leakage which must be given to the insulator in order to balance the same.

Fig. 26

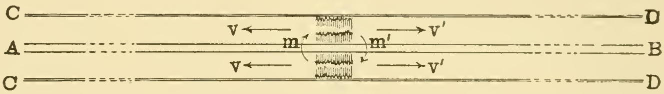


Fig. 27

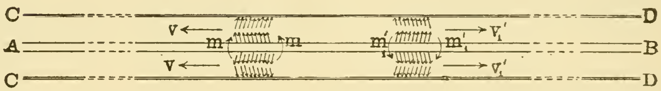
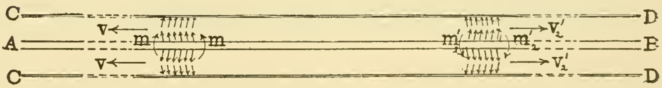


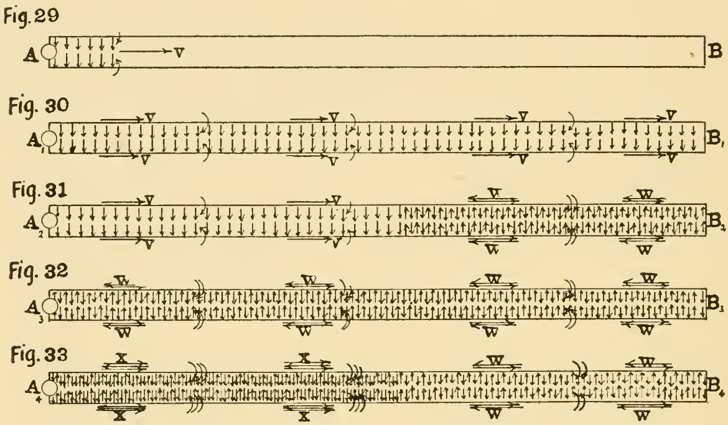
Fig. 28



FIGS. 26–28.—Movement of Electric Flux in Distortionless Cable.

Fig. 28, represents the condition of attenuation without distortion at the later stage in the process.

We have hitherto assumed that only a metre block of electric flux was started from the centre of the circuit, and that this was called into existence in some special manner. We shall now consider what takes place when an electric source, such as a dynamo or battery, is connected permanently between the wires at one end of the circuit. In Fig. 29, a dynamo is supposed to be connected at the end A, the positive pole to the upper wire and the negative pole to the lower wire. The dynamo is assumed to have no resistance, and the distant end of the line is short-circuited at B. The moment the connection is effected, electric flux is supplied from the dynamo to the insulating medium between the two wires. The rush of electric flux which escapes from the dynamo constitutes the electric current which it supplies, and if a certain imaginary unit quantity of electric flux constitutes a *coulomb of electricity* (the practical unit of electric quantity), then the number of coulombs of electric flux, uniformly supplied per second from the generator, represents the number of amperes of electric current supplied to the circuit. If the pressure of the generator is 1000 volts, then the difference of potential between the wires at A, is 1000 volts, and these two wires we may first assume to be per-

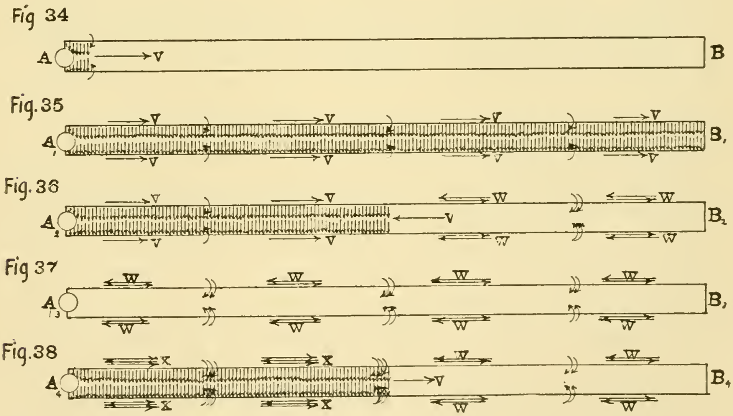


FIGS. 29–33.—Movement of Electric Flux in Closed Circuit of Perfect Conduction and Insulation, when Supplied by a Generator of no Resistance at One End.

fectly conducting. The arrow v, in Fig. 29, represents the initial direction of flux rush, from A towards B. As the flux moves along towards B, with the velocity of light, more flux comes out of the generator. The function of the generator is to supply flux to the insulating medium with which it is connected by the wires. The curved arrows represent the direction of the magnetic flux distribution which everywhere accompanies the moving electric flux.

Fig. 30, represents what takes place by the time that the vanguard of electric and magnetic fluxes has reached the end B. The entire insulator between the two wires is now full of electric flux at the particular density furnished by the dynamo at its pressure. With perfect conduction and perfect insulation there has been no loss of energy, and the magnetic flux and electric flux are just as dense at B, as they are at A. Reflection with reversal of electric flux takes place at the short-circuit under B_1, so that, as shown in Fig. 31, the vanguard of electric flux can rush back towards A_2, after reflection from B_2, and having the direction represented by the upward arrows, so that, at and near B_2, as much electric flux is now pointing downwards as pointing upwards. There is, consequently, no resultant electric flux near B_2, although there is twice as much electric flux, considered without regard to direction. The magnetic flux is, however, doubled as determined by the reasoning accompanying Fig. 15.

After the proper interval of time has elapsed, the vanguard of electric flux has arrived at A_2, while further flux is all the time pouring out of the dynamo; this condition is represented in Fig 32. It again reflects at A_3, with reversal of electric flux, and advances once more towards B_4, Fig. 33, in the original direction, so that there are now two streams of downwardly directed electric flux, and one stream of upwardly directed flux, leaving as a resultant a single stream, but the magnetic flux is trebled in density. The resulting



FIGS. 34–38.—Movement of Electric Flux in Closed Circuit of Perfect Conduction and Insulation when Supplied by a Generator of no Resistance at One End.

condition is represented in Figs. 34 to 38, which correspond respectively to Figs. 29 to 33. In the first passage between A_1 and B_1, the electric flux fills the entire insulator. In the next passage between A_3 and B_3, Fig. 37, the electric flux entirely vanishes by a process of cancellation of oppositely directed streams, but the magnetic flux is doubled. In the third passage from A_4 to B_4, Fig. 38, there is a reappearance of the original electric flux and potential, but with the magnetic flux trebled. In the fourth passage, not shown, there is a disappearance of electric flux with the magnetic flux quadrupled, and so on indefinitely. The current strength, which is always measured by the density of magnetic flux, continually increases by successive leaps at each succeeding passage, but the electric difference of potential between the wires oscillates between the original quantity of 1000 volts and zero. After an indefinitely long period from the start, the current carried by the circuit will be indefinitely great, and this corresponds to what Ohm's law would prescribe in a case of perfect conduction.

Any actual circuit of perfect insulation but imperfect conduction would differ from this case in the fact that the vanguard would be continually subjected to attenuation and distortion, so that it becomes less and less observable in its passage at each successive traverse of the circuit. Finally, after a certain interval of time has elapsed, no further accretion of electric or magnetic flux is perceptible. The rate of dissipation of energy taking place into the conductor, all along the circuit, would then be just balanced by the rate at which further flux energy is pouring into the circuit from the generator. This is the condition which is determined by Ohm's law for the case of a definite resistance and perfect insulation. The effect is to lower the pressure to zero at the distant end of the circuit, and to maintain a uniform strength of magnetic flux distribution all through the circuit. Consequently, when the steady state has been attained under the influence of imperfect conduction and perfect insulation, the potential falls steadily from the source towards the distant end, but the magnetic flux-rush is constant throughout. The electric flux-rush is, therefore, also constant at all parts of the circuit, but some of the rush is directed upwards and some of it is directed downwards, so that at the distant end there is no resultant electric flux, while at the generator end the resultant electric flux is at full density.

This condition is represented in Fig. 39. Here the outrush from the dynamo is indicated by the long flux arrows pointing downwards. As these reach the BD end of the circuit, they are shortened in length, to indicate that the flux density has suffered diminution by attenuation on the journey. The reflected stream is then shown by the reversed arrows, which shorten in length as they return to the generating end. These are again reflected with reversal, and the shortening process continues from end to end until the stream is no longer perceptible. The contrary movement of the tailings is omitted, for convenience, from the diagram. At E_1, these various stages of the stream are indicated by the horizontal arrows. The first is a long arrow e_1, representing the outgoing stream of full strength. Then come a pair of oppositely directed arrows indicating the passage of the stream on return to AC, with reflection therefrom; then similar pairs of oppositely directed arrows for succeeding returns of the stream, each time weaker and weaker, until finally no longer perceptible. The sum of all these is the first arrow e_1, since all the rest are in pairs which cancel. Consequently, the electric flux at E, has the resultant e_1, or the full strength and density of issue from the dynamo, as shown at E'_1, which represents the voltage or potential difference between the wires at E_1. If the voltage of D, is 1000 volts, E'_1, is 500 volts positive, and E''_1, 500 volts negative.

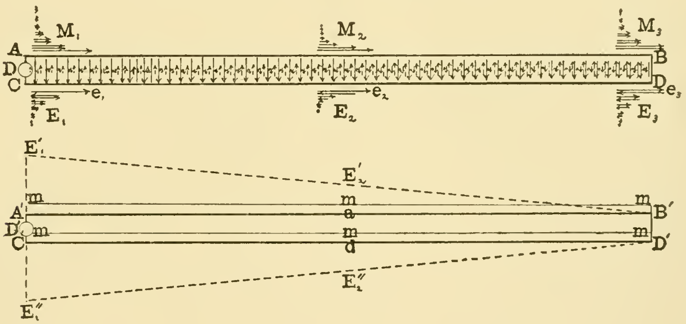


FIG. 39.—Distribution of Electric Flux Streams in Conformity with Ohm's Law in a Perfectly Insulated Closed-Circuit.

Again at the BD end, the electric flux streams are indicated at E_3. First come two opposite arrows e_3, representing the first arrival of the stream and its immediate reflection with reversal. Then follow successive pairs of oppositely directed shortened arrows. The sum of all these is clearly zero, so that the resultant flux density at BD, is zero, and there is no resultant voltage or potential difference. At B′D′, therefore, the dotted lines indicating potential fall to zero or join the lines A′B′ C′D′.

Again, in the middle of the line at E_2, there is a series of successive arrows, none of which entirely cancel. Their sum, however, is half e_1, and at ad, the voltage E'_2, E''_2, falls on the dotted lines E'_1 B', E''_1 D'. The same is true for any other point on the line. Consequently, the pressure falls steadily from AC to BD.

It is otherwise, however, with the magnetic flux which undergoes no reversal. The development of this is shown at M_1, M_2 and M_3. The arrows are all of equal length to the corresponding electric flux arrows at E_1, E_2 and E_3, but there is no reversal of direction. The sum of all these sets of arrows is constant at all points of the line, and this condition of constancy in total magnetic flux is represented by the horizontal straight lines m, m, m, m, m, m. In other words, the current strength is constant.

The rate at which energy is being transferred from the dynamo along the circuit past any point is simply the sum of the electric and magnetic energies contained in the various passing streams of flux, the summation being made with regard to the direction of these streams. Thus the first stream may carry past the point considered 1,000,000 ergs in each second, half in magnetic energy, and half in electric energy, the second stream may carry 500,000 ergs backward, the third 250,000 forward, and so on; the resultant stream in this case being 666,667 ergs per second forward, and this is the activity of the circuit at the point considered.

According to these views, therefore, the electric current, which is electric flux-rush, is invariably transmitted with the velocity of light in the ether of the particular insulator considered. But the actual velocity with which an electric impulse travels along the circuit, as measured by the time which elapses between the connection of the source at the generating end and the appearance of energy at the receiving end, always tends to be less than this velocity, because, owing to attenuation and distortion, the first impulse or block of flux may be completely absorbed and dissipated before it can reach the distant end with the velocity at which it travels, and further flux must gradually come up from the source and suffer attenuation and distortion, before the vanguard can finally arrive at the receiving end and perform its allotted function. It is for this reason that a submarine electric cable between say Ireland and America, takes nearly $\frac{1}{7}$th of a second before an electric signal or impulse transmitted from one end will make its first appearance at the other, although the time that an electric wave would take to traverse its length would be only say about $\frac{1}{60}$th second. The original impulse traveled so far as it went with the velocity of light in the ether of gutta-percha, but the vanguard was completely dissipated and the successive vanguards were attenuated with complete dissipation for a comparatively long time before the distant end could be reached.

It is only on long circuits, such as are afforded by telegraph and telephone wires or submarine cables, that the phenomena of electric transmission with their attendant distortion and attenuation are most clearly evidenced. In the comparatively short circuits employed for transmission of electric light and power, the phenomena of distortion and attenuation of electric and magnetic flux are of little practical importance. Fig. 40, represents the signals sent over

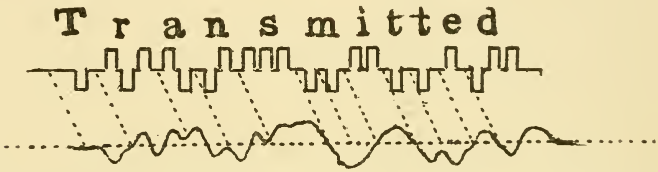


FIG. 40.—Distortion of Signals Received Over Last-Laid Atlantic Submarine Cable.

the last laid Atlantic cable and the corresponding signals which were received at the distant end. The two should be exact facsimiles and should, therefore, be capable of actual superposition if no distortion occurred in the electric impulses. Not only the delay or retardation in the received signals, but also the great distortion which is noticeable, are due entirely to the fact that there is very little leakage in the insulator, while there is very appreciable resistance in the conductor. This cable, laid in 1894, has a published length of 1847.5 nautical miles. The copper conductor offers a resistance of 1.68, or about $1\frac{2}{3}$, ohms per nautical mile, while the insulator has a resistance of 85,000,000,000 ohms in each nautical mile. This cable has a working speed of over forty-five words per minute, which is much faster than any other previously laid Atlantic cable, owing to the greater conductance of the circuit. This cable possesses, of course, enormous distortion, although such distortion does not prevent signals being read until a speed of over 225 letters per minute is attained. If, however, the insulation, instead of being 85,000,000,000 ohms in each nautical mile, were reduced to about 500 ohms in the nautical mile, the leakage tailings would probably balance the tailings due to imperfect conductance and the cable would be distortionless. The signals received would, therefore, be the exact counterpart of the signals sent, and an indefinitely high speed of signaling should be possible. In respect to absence from distortion, such an Atlantic cable would transmit telephonic speech waves perfectly. It would, however, possess so much leakage that the received signals would be far too attenuated and feeble to perceive. The conductor would only offer at the sending end a resistance of, approximately, 28 ohms, instead of 3108 ohms, the total conductor resistance, and the current strength which would flow from the receiving end to ground would be, approximately, 5×10^{47} times less than the current entering at the generating end. No telegraphic or telephonic instrument at the present time could detect so feeble a current as this. Moreover, if any accident happened to such a cable it would be impossible to localize the position of the fault unless the same occurred within a mile or two of either end. Consequently, the distortionless circuit does not provide at the present time a practical solution for trans-Atlantic telephony. About one hundred miles is, probably, the limiting length of this particular cable, with its good insulation, over which telephonic speech can be carried.

We have not considered the mechanism whereby the electric and magnetic flux, when it reaches the receiving end, is absorbed and its energy utilized for the performance of any kind of work, such as the operation of a motor, the production of signals, or of articulate speech. It has been sufficient to point out that the electric current runs through the insulator from one end of the circuit to the other, and is guided by the two conductors, which with the insulator form the circuit. If it were not for these two conductors, any electric wave or impulse would radiate out into space in all directions, like light from an unprotected candle. The wires do for the electric wave what a reflector does for the search light; namely, localizes and concentrates the beam into a single path, whereby it may be transmitted to the desired point with the minimum attendant loss in transmission.

Discussion.

Mr. Paul A. N. Winand said:

I have been very kindly invited by the authors of the paper to participate in its discussion. I wish to express first my appreciation of the remarkably thorough, clear and original manner in which they have accounted for the conditions which exist *in the space surrounding the conductor* in the phenomenon called electric current. In fact I could not attempt to add anything to this very clear exposition. I have therefore collected the objections that can be raised against some of the views and conclusions of the authors.

We first encounter a difficulty as long as we do not bear in mind the dual nature of the electric flux considered in relation to electrostatic conditions. The flux is to be taken, respecting one of its manifestations, as a measure of electric quantity inasmuch as, when rushing, each unit will produce the same magnetic flux, but this effect is independent of the difference of electric potential. The energy transferred is, however, proportional to this difference.

In the case represented by Fig. 39 of a perfectly insulated closed circuit, the quantity of flux, owing to the perfect insulation, must remain unchanged as it rushes along the line, but the other factor in the transfer of energy, due to the rush of flux, the difference of potential, decreases as the energy is transformed into heat in the conductor. If I understand the authors correctly, they consider the process as entailing a diminution of the first factor (quantity) by partial reflexions constituting the imperfect conduction, while the second factor remains unaltered. It is difficult to see how, with perfect insulation, at any point of the line, where such reflexions occur (the reflected fractions of flux returning towards the origin), energy will cease to be electric and become thermic, since the reflected fractions will carry their energy away undiminished from that point, while the unreflected part of the flux will carry its share away in the primary direction of main rush.

As to the view held by the authors that the electric current runs through the insulator, or, more broadly, through the space outside the conductor, and is merely guided or localized by the latter, it seems to me open to some grave objections. It is true that the old view, which considered the conductor as the only real seat of the phenomenon, is not tenable. But there is another intermediate position, which has been expounded by Poynting, Lodge, J. J. Thomson and others, which is: that while the current flows through the conductor, the energy, which is generally transferred simultaneously, travels through the space surrounding the conductor.

As stated by Lodge: "We must learn then to distinguish between the flow of electricity and the flow of electric energy; they do not occur along the same paths. . . . . Electric energy is not to be regarded as pumped in at one end of a conducting wire and as exuding in equal quantities at the other. The electricity does indeed travel thus, whatever the travel of electricity may ultimately be found to mean, but the energy does not.'' Poynting expresses it thus: "Formerly a current was regarded as something traveling along a conductor. But the existence of induced currents and of electromagnetic action at a distance from a primary circuit, from which they draw their energy, has led us, under the guidance of Faraday and Maxwell, to look upon the medium surrounding the conductor as playing a very important part in the development of the phenomena.''

I am not prepared to abandon this intermediate point of view for the reasons which I shall presently state. It naturally depends to a great extent on what we are to understand by an electric current. The nature of electricity being unknown, this phenomenon can only be dealt with as a sum of correlated effects. Some of these occur in the conductor, some in the space outside of it.

One fundamental relation was obtained when it was proved by experiment that the translatory motion of a charged conductor produced the external effects of a current; the effects otherwise found in the conductor being then absent because the conductor moved with the charge and with its external condition or electric flux.

It might be argued that the conducting body, say a charged sphere, should be considered as being mainly a discontinuity in the surrounding insulating space and that the displacement of this discontinuity created the effects by disturbing the space. The experiments of Rowland, however, have established that a rotary motion of a plane conducting disc around its axis produced the same external effects as a current and in this case the conductor, considered as a discontinuity in the insulating space, did not change its position. Does this not tend to show that the unknown condition which moves bodily with the substance of the conductor in the one case moves along the conductor in the other case, which is called current proper?

On the other hand we find that in the case of current proper, effects are produced within the conductor, and we find also that these effects occur not merely at the boundary between conductor and surrounding space, but throughout the cross-section of the conductor. This is undoubtedly true of the heating, the electrolytic effects, osmotic effects, migration of the ions, actions at the electrodes, some luminous effects (as in gases), thermo-electric effects broadly and of some magnetic effects. It is an established fact that when a conductor carries a so-called current the magnetic lines of force or flux do not exist only in the space around it, but they are present also within the cross-section of the conductor. Their density is, however, smaller at points inside the cross-section than at points immediately outside of it and at the centre of a circular homogeneous cross-section this density is equal to zero. Does this not clearly point to the conclusion that the action which produces the field in the surrounding space has its seat in the cross section of the conductor and extends throughout the same?

Even for effects such as those of so-called free static electricity which seem clearly to have their seat at the boundary between the conductor and the space surrounding it, can we disregard the conductor which is an essential part of the apparatus, though the effects so far discovered in such cases seem to reside in the surrounding space?

Turning now from the consideration of continuous currents to that of very rapidly alternating or freely alternating currents which generate waves of electromagnetic disturbance in space, as first demonstrated by Hertz, we find that, on connecting the charged conducting bodies, the disturbance originates on these bodies and gradually spreads into space with the velocity of light. The phenomenon starts with a current having its seat on the conducting bodies and the surrounding space is affected subsequently, as by light emanating from a spark. Is it then not natural to consider the conductor as the seat of the current and as the primary factor in the apparatus?

In view of these considerations, I cannot but retain the point of view stated above, though I am ready to admit that, as the changes of distribution of energy take place through the surrounding space, the latter may be considered as more important than the conductor. It should not be forgotten, however, that we can only postulate but not demonstrate the travel of energy, while we can measure its disappearance at one point and its appearance at another. We can only find changes in the distribution of energy. Now if we consider a conducting circuit of inappreciably small resistance; a current of any strength can be existent without a comparatively appreciable change in the distribution of energy, which shows that even the practical importance of this action is not always evident.

Dr. A. Macfarlane: I wish first of all to express my sense of the admirable manner in which the authors have carried out the aim which they set before themselves. Behind their description of the manner in which an electric current is now believed to be transmitted there is a great amount of mathematical analysis and experimental verification.

In a work on the *Applications of Electricity*, written by Count du Moncel before the beginning of the great industrial development of electricity, he refers to a fanciful plan of a M. Charles Bourseul for transmitting speech by electricity. The Count makes great fun of the idea; yet he lived to write a book on the telephone. What struck him as especially absurd was that vibrations produced by the human voice could be thought capable of transmission through a solid wire of copper. And indeed it is wonderful how electricians have been so long content to regard the current of electricity as transmitted by the copper molecules, or even by the ether in the wire between the molecules.

In the study of electrotechnics there is nothing more important than clear ideas about the relation of the electric current to the associated magnetic flux. It is important to observe that there are many analogies between the two; but it is also important to observe that the analogy is not complete. The electric current involves in its idea the element of time in a way that the magnetic flux does not. Now observe how the theory expounded explains this. We have the complementary ideas of electric flux and of magnetic flux and also the other two ideas of rush of electric flux and rush of magnetic flux; the electric current in general meaning motion of the combined flux.

For some time it was customary to neglect the study of static electricity because its connection with current electricity was not evident. But observe that the one idea—electric flux—comes from the old science of static electricity, and the other idea—magnetic flux—from the old science of magnetism: together they explain the phenomena of the flow of electricity along a conductor.

In the text-book of *Electricity and Magnetism* which I studied there was an article headed "Velocity of Electricity." Account was given of some experiments made to determine the time required for the transmission of signals along conducting lines; the disagreement of the values obtained was pointed out, and the writer concluded that properly speaking there was no such thing as the velocity of electricity. But observe how the theory expounded rests on that very idea, how it explains all the seeming contradictions, and shows what in certain cases reduces the velocity of electricity from that of the velocity of light in the ether.

Stated Meeting, April 2, 1897.

Vice-President, Dr. PEPPER, in the Chair.

Present, 45 members.

Correspondence was submitted.

Mr. Pettit, on behalf of the Curators, presented a report, recommending that the North Room be fitted up for the use of the Cabinet.

Dr. Pepper presented the report of the Special Committee on the Needs of the Library.

The following resolutions were then adopted :

1. That the immediate needs of the Library demand that the North Room be devoted to its purposes.

2. That the Peale Collection be maintained in the North Room for the present.

3. That the collections of plants be transferred in trust as a deposit, subject to recall, to such institution as may be ordered by the Society.

4. That the duplicate collection of rocks be submitted to a Committee of Geologists (Messrs. Lyman, Prime, Frazer and Platt), to report to the Society their recommendation as to its disposition.

5. That a Special Committee of nine (Dr. Pepper, Messrs. Harris, Pettit, T. H. Bache, Price, Frazer, Stone, Jos. M. Wilson and Hays) be appointed to adopt plans for the adaptation of the North Room for the above purposes and to make suitable provision for the other objects of the Society, and that the Hall Committee be empowered to expend a sum not exceeding one thousand dollars in carrying into effect the plans so adopted.

A letter from Judge Mitchell on behalf of the Commission to collect and print the Statutes at Large of Pennsylvania, from the foundation of the colony to the year 1800, asking that the Society grant it the privilege of using a volume of

MS. copies of laws prior to 1700, in the possession of the Society, was received.

Dr. Hays stated, in connection with Judge Mitchell's letter, that he had a few days ago incidentally called the attention of Dr. Frederick D. Stone to a manuscript volume of laws of the Province of Pennsylvania, passed prior to November, 1700, which had been presented to the Society in 1835, by the late Joshua Francis Fisher, Esq. Dr. Stone at once recognized that the volume might have a very important bearing on the work of the Commission appointed in 1883 by the State of Pennsylvania to examine and collate, and authorized some years later to publish, the complete text of the Statutes at Large of Pennsylvania from the foundation of the Province, 1682 to 1801, of which the second volume (the only one yet issued) has just been presented to the Society by the Commission. The principal reason why the Commissioners had delayed the printing of the first volume was due to the fact that certain laws, twelve in number, noted in the minutes of the Provincial Council as having been passed prior to November, 1700, which date was adopted as the starting-point of the second volume, could not be found. Official inquiries made at Harrisburg, and at the Public Record office in London, elicited replies that no such acts were in the possession of the State or of the English Government. Fruitless search was also made at West Chester, at New Castle and at Dover, as certified copies of the acts, as passed, were then usually sent to the clerks of the several counties. The Penn papers and the early manuscripts in the collection of the Historical Society of Pennsylvania were carefully examined in vain, and the Secretary of the Commission, Mr. Charles R. Hildeburn, personally made a thorough but fruitless search in the Public Record Office in London for these missing laws. Of all this Dr. Stone was fully aware, and he at once suggested that the attention of the Commission be called to the volume shown him.

Mr. Justice Mitchell, the Chairman of the Commission, and Secretary Hildeburn, upon being informed of the existence of this valuable and important volume in our Library, at once subjected it to careful examination and found that it contained many of the laws passed prior to November, 1700, including the twelve missing ones, viz., one act passed June 9, 1694; two acts passed February 10, 1699–1700; one act passed May 16, 1700, and eight acts passed June 7, 1700. Some in not quite as satisfactory form as could be desired, but most of them duly attested by the Speaker of the Assembly, signed by Governor Fletcher, and the later acts by Governor Markham, and sealed with the "Lesser Seal" of the Province.

It is interesting to note, in this connection, that the use of the "Lesser Seal" for such a purpose was a most extraordinary proceeding, and can bear no other explanation than that it was done by William Penn's orders with a view to his claim to a veto power, which was subsequently denied him by the Crown, as the later acts are all passed under the "Great Seal" of the Province.

The only copies of the laws passed prior to November, 1700, possessed by the State and from which the Commission had intended to print, consist of unattested copies made by Patrick Robinson, Secretary of the Council. Hence the Commissioners now desire to print from the duly attested copies of these laws belonging to this Society, rather than from the unattested copies belonging to the State.

It is surmised that the copies contained in the volume belonging to the Society may have come into the office of Andrew Hamilton during the period when he was Attorney-General of the Province, and were acquired by Mr. Fisher in the course of his examination of the Hamilton papers deposited at "The Woodlands."

The finding of these acts will place the Commonwealth of Pennsylvania in possession of a complete set of its legislative enactments, from the founding of the Province to the readily accessible "Pamphlet Laws" beginning with 1802. All but two of the original thirteen States of the Union have, at one time or another, attempted to make and publish similar collections, but not one has succeeded in gathering together all its laws, but now, with the use of the volume which Mr. Fisher with intelligent discrimination rescued from oblivion or worse, and which the American Philosophical Society has so carefully preserved, Pennsylvania will be the only American Commonwealth that is able to present to the world an unbroken series of its own laws.

The following resolution was then adopted :

That permission be given to the Commission for the Compilation of the Laws of Pennsylvania prior to 1800, to refer to and to copy, if they so desire, the MS. volume of original laws of Pennsylvania from 1683 to 1700, presented to this Society in 1835, by Joshua Francis Fisher, Esq., under such regulations as the Library Committee may prescribe.

Prof. Robert W. Rogers, of Drew Theological Seminary, Madison, N. J., and Prof. Morris Jastrow were appointed delegates to the Congress of Orientalists to be held at Paris this summer.

The Society was then adjourned by the presiding officer.

Special Meeting, April 23, 1897.

President FRALEY in the Chair.

Present, 20 members.

Dr. Morris read a paper on "The Relation of the Dodecahedron found near Marietta, O., to Shamanism," which was discussed by Mr. Cushing.

Dr. Harrison Allen laid before the Society a chart of Australian rock carvings, by R. H. Matthews.

The Society was then adjourned by the President.

RELATION OF THE PENTAGONAL DODECAHEDRON FOUND NEAR MARIETTA, OHIO, TO SHAMANISM.

BY J. CHESTON MORRIS, M.D.

(*Read April 23, 1897.*)

I regret that I am unable this evening to present to the Society, as I had hoped, a very intelligent and well-educated Néz Percé Indian, Mr. Lewis D. Williams, who called upon me some two months ago and read a paper which he had prepared on the education and training an Indian boy receives in his native home. It recalled vividly to me Dr. Brinton's communication to us two years ago on the Nagual form of worship (*Proc.*, Vol. xxxiii, pp. 4, 11, 73), and I had hoped to secure his presence. Unfortunately I have lost trace of him (as he is no longer in the employ of the Bureau of Am. Ethnology at Washington), and can therefore only give a résumé of it from memory. He left his tribe when about fifteen years old, was educated at Carlisle and the University of Pennsylvania, before entering the employ at Washington of the Bureau of Am. Ethnology. He spoke of the boy's close observation of nature in the world around him and his companions, of the inquiry which arises in all human hearts as to the meaning and object of life, and the forces which are displayed, the means of utilizing them, of obtaining success: of the belief in hidden unseen powers controlling or directing or opposing our efforts: of the brave hunters and successful warriors, of the older wiser rulers, of the medicine men and the ceremonial dances and rites of the tribe. He told of the time when the boy hitherto nameless must take, or have given to him, a name. What shall it be? He told the myth that once on a time a wise medicine man had a sacred tepee; to him came the beings which became the various animals and birds, each with its own ambition. One would come and say, "I want to be an eagle." "Well, let me see how you can fly." Off he soared, and came back after flying up toward the sun, and was received with the encouragement, "All right, go and be an eagle." Another wanted also to be an eagle, but only fluttered a little way, lit upon a tree and came back chattering, to be told, "No, you can't be an eagle, you must be a bluejay." Another showed ability, and was allowed to become, at his desire, a wolf. Yet another, trying to run like him, only ambled around and sat upon his haunches to be told with a laugh, "No, no, you can only be a coyote." (This reminded *me* of the bringing of the animals to Adam for their names.) Filled with longing to know his fate in life, the boy goes off into the forest, and communes with nature. He longs to be something, somebody. He tests his powers of endurance, his skill, his desires. Many and long may be his rambles in this effort to place himself in his proper niche in the world. He becomes dreamy—he longs to see a vision or to have some sign to direct him. Perhaps some night one of these unseen spirit forces may make itself known to him. At last, one night when all alone on the mountain side, he sees, or thinks he sees, a wolf approaching, who comes and talks to him, encourages him, lays open his career of duty to him, and tells him if he will be brave and faithful he will aid him and cause him to triumph over every difficulty, bids him come close to him and pluck some hairs from his neck and keep them always with him so that whenever he is in trouble he can by pressing or rubbing them call his guardian spirit to his aid and thus be enabled to succeed and triumph over his difficulties or enemies, or receive counsel in emergencies. The boy returns home, tells his experiences, is tested, and if found truthful and brave is initiated into the lodge under the guardianship of the wolf which he takes as his totem; and in the sacred dances wears the appropriate symbolic mask. Little by little, year after year, as he shows himself fitted and acquires more knowledge and experience, learns more of the legends of the tribe in which are crystallized the results of their contact with nature and their reasonings upon it, he is advanced more and more, and becomes a medicine man, or an elder, or chief, taking part in the councils and directing the affairs of the community. The older, wiser, more reliable he becomes the more respect is shown him.

The idea, so common among us, that their medicine men are all mere quacks and humbugs, charlatans of a low grade, and that all their dances are low orgies and mere devil-worship—that the Indian is an untutored, untrained savage, bloodthirsty, revengeful and treacherous—is largely erroneous, and due to a lack of proper and adequate knowledge of him as he really is: and of consideration of his circumstances in the world. Place a human being of average capacity of any other race in similar conditions, and the probabilities are that his chances of survival would be less, to say nothing of the system of a philosophy of the unseen but no less real forces around, above and within him which he has developed. He is in many respects a child—and so we too are but "children of a larger growth." When things hurt or oppose him, or others injure him, he grows angry and avenges himself unreasoningly and excessively, as a child would. Higher aims and purposes he has little chance to acquire. Yet there is the yearning for the higher, the better—for the pure and true, for the brave and good: when these are shown to him he seizes upon them and grows to the full stature of man. How often this has been shown—and yet how often it is ignored!

In every age and clime, among every race, there have been and are those who have sought to know more of the truths around, above and in them—men who have risen above their fellows, and have been looked up to as leaders and advisers of the rest—and also in every race and age these men have been credited with supernatural powers—have been supposed to be in communication with the world of spirits: and too often alas they have used their attainments only for their own selfish ends: have availed themselves of the ignorance and superstition of those beneath or around them and by trickery have magnified their influence. If we, however, think of the meaning of such terms as "soothsayer," "wahrsager," "wise heart" (wizard), "astrologers," "magicians," and think of their succession in the history of our race, from that of the wise men of the East, Balaam, Jannes and Jambres, the Pythian and Delphic oracles, the Roman augurs and haruspices—nay, even of Paracelsus, who may almost be called the father of modern physiological medicine, we shall have less disposition to condemn so utterly the Indian medicine man: especially as we read of Daniel, who was made and seems to have accepted the post of "chief of the magicians, soothsayers, astrologers and Chaldeans." In fact, the yearning after occult science is as powerful and prevalent in Paris, London and Berlin, not to mention among ourselves, as in India among the Brahmins and Buddhists—it is a human yearning. To penetrate the secrets of or to forecast the future—to resort to some species of divination—to seize upon and compel the unknown, is so human that Goethe makes it the aspiration of his Faust.

We need not wonder then that Shamanism, the idealizing and spiritualizing of the forces of Nature, became so prevalent among the children of the forests and mountains, of the plains and sea-shores, of the New World as it did in the Old; that mystic dances, rites and symbols abound among them—that Nature speaks to them with myriad tongues: that they should try to penetrate her secrets by methods of divination more or less analogous or identical with those of similar races. But here comes in a factor which is too often disregarded—the influence of race. Truth, absolute truth, must always remain the same: not so our appreciation of it, which must in every case be more or less partial, more or less incomplete. Some races have little or no idea of harmony—others of lapse of time—others of liberty—others of home. The Western races of the Old World view things objectively, the Eastern subjectively. The Indian resembles the latter—the world is in him and he is of it. Our Aryan brains take readily the idea of three dimensions in space. To the Indian, and to the Eastern mind, there is another—the fullness. It is hard for us to grasp this—it is not the length and breadth and thickness of a cube for instance, but the whole of it, which is as much to be considered as any one of its sides. A cube would, therefore, be represented numerically by 7: a dodecahedron by 13. Among the Mexicans the thirteen lunar months would thus correspond in the year with the twelve zodiacal signs and the earth which passed under and embraced them all. Again, the five digits on each hand came to be a measure of a man's power or individuality, and thus a sacred number. It would then require but little stretch of imagination to suppose that a pentagonal dodecahedron, were such a form known to them, inscribed with zodiacal characters, might be the emblem of the world: and the best time for the activity of a man in some pursuit in which he might wish to engage might be shown by the zodiacal sign which came uppermost when the dodecahedron was thrown or rolled with appropriate ceremonies.

Such is the hypothesis which I would offer as to the character and uses of this curious stone dodecahedron, which was sent to the Society on October 19, 1792, and has since been lying in the Cabinet. The record shows it to have been taken from a bluff on the Ohio river, about thirty miles above Marietta; and it was sent here with other Indian relics. The edges show slightly conchoidal fracture: the sides are finely polished, showing also indistinctly drawings of figures upon them which have been made, Mr. Cushing thinks, with stone tools: it is black, of moderate hardness, sp. grav. about 2.78, and effervesces with dilute acid.

In Vol. xxi, Pls. i, ii and iii, of the *Proceedings*, some drawings are given of the Pictured Rocks on the Monongahela, showing good examples of the Shamanistic symbol writing of the tribes which roamed there before the advent of the white man, and I have the pleasure also of exhibiting casts made from impressions in plaster taken from some rocks in the Susquehanna at Safe Harbor, Lancaster county, Pa., and presented through Prof. T. C. Porter, by the Linnæan Society of Lancaster county, figured in the *Proc.*, Vol. x, pp. 30, 255, and Pls. i and xiii. These figures, cut by stone implements in the limestone rock, give striking representations of the sacred dances participated in by Indians wearing masks, and of various mythic creatures such as the thunder-bird, etc.

The 12 faces of the figure may be divided into 4 groups of 3 faces each, forming 4 solid angles, which may be connected so as to form the four-legged Sphastica: or those may be united to form a triskele. There are in all 30 dividing edges and $12 \times 30 = 360$; add a 5 and you have the days of the year. The 13 (sum of the faces and the object itself) multiplied by the 4 points above noted gives the number 52, the Aztec cycle—while 4 adjacent faces, each with 5 sides, would give 20, the unit of a man. Or, again, 3 edges unite so as to form 20 three-sided points. Thus the cube and pentagonal dodecahedron might be used to represent all the mystic numbers. While those of the cube were connected more with the extreme orient, those of the dodecahedron may be found there as also in Egypt and Mexico.

I cannot refrain from the suggestion that perhaps this dodecahedron may throw some light on the customs and civilization of the mound builders of Ohio.

Discussion.

Mr. Frank Hamilton Cushing, in response to a request of the President, commented upon and discussed the subject at considerable length.

After a few general remarks relative to Shamanism, or, more properly, Primitive Priestcraft, which he defined as the outgrowth of the "Religion and Philosophy of Mystery," of the attempted explanation of the unknown,—the realm of which, he stated, grew greater and greater as we progressed farther and farther backward in time and the history of human culture growth,—he expressed himself as follows:

The account Dr. Morris has given us as to what Mr. Williams related to him concerning the life of an Indian youth of the Nez Percé tribe has interested me exceedingly by reason of its striking similarity to what I have myself heard, seen, and experienced among the Zuñi Pueblo Indians of New Mexico.

With these people, a child is not thought of, when first born, as quite yet a living *mortal* being. It is referred to as "it" or the "new being," nor is any name given to it until after the lapse of nine days. It is supposed to be *kăi'-yu-na* and *aĭ'-ya-vwi*—unripe and tender, or soft and susceptible as are germinating seeds or unfinished clay vessels, until after one full day for each of the lunar months of its inter-uterine gestation has passed. During this period of nine days it is usually kept with its mother, secluded from the outer world and from sunlight, in order that it may gradually become hardened to, and so, safe in the "world of daylight"—as these people term the scene and condition of mortal life—that is, condensed to "middle being"—as they further term man's particular mortal existence.

At the close of this ceremonial period the umbilical cord, which has meanwhile sloughed off or has been removed and zealously cared for, is ceremoniously buried in the soil at some particular place, in order that thereat may be formed the "midmost shrine" of the child, and therein its connection with the earth mother—as formerly with its mortal mother—may be established, and that its vitality apart from her thenceforward, be maintained—by thus placing within the fertile bosom of the Universal Mother, that through which erstwhile the child received separately, or secondarily, its being nourishment and growth, from its human mother.

Passing over many other ceremonials which attend the first naming of the child, its introduction to the Sun and to the tribe of its descent, on the early morning of the tenth day,—that is, at the end of these nine natal days,—a few words relative to the meaning of the "midmost shrine" will serve to indicate what would likely be the symbolic significance to a people like the Nez Percé and the Zuñi Indians, of such an object (whether natural or artificial) as the one to which Dr. Morris has called our attention.

He has quite accurately stated, in the theory he has advanced regarding this object, the view one of these Indians would hold, as to the meaning of the *number* of its sides or faces and itself. To one of them, a cube would not be representative of six, its number of superfices, but of *seven;* and a dodecahedron, not of twelve, but of *thirteen*. For, when an untutored or primitive man like him, contemplates or considers himself or any other distinct thing, in his or its relation to space or the surrounding directions, he notes that there is ever a front or face, a rear or back; two sides, or a right and a left; a head and a foot, or an above and a below; and that of and within all these, is himself or it; that the essence of all these aspects in anything, is the thing-itself—that is, the thing that contains their numbers or sum, yet is one by itself.

This is indeed the very key to his conception of himself and of everything, in relation to space and the universe or cosmos. He observes that there are as many regions in the world as there are aspects of himself or sides to any equally separate thing; that there are as many directions from him or his place in the world (which is his "midmost" or place of attachment to the Earth-mother) or from anything in the world (which is *its* midmost or natural station) toward these corresponding regions. Hence to him a plane would be symbolized not by four, but by *five*, its four sides and directions thence, and its central self—as was actually the notion of the Prairie tribes; a cube, not by six, but by seven, as was the notion of the Valley-Pueblos and Navahos; a dodecahedron, not by twelve, but by thirteen, as was the notion of the Zuñis, the Aztecs, the Mayas, and apparently—from this example—of the Mound builders as well.

With all that I have thus far said I cannot yet have made clear to you the relation this supposed connection of beings and things to their surroundings, to the regions in front, behind, at the right and left sides, and above, below and within them, can have to the subject under discussion. It will therefore be necessary for me to crave your patience while I enter a little more fully into a consideration of the beliefs of primitive man concerning *force*, *life*, and *form*, for it will be seen that these beliefs have a direct bearing on this apparently fantastic and mystic meaning of the numbers *seven* and *thirteen*.

To the primitive Shaman, all force necessarily seems to be derived from some kind of life, since he continually sees force as motion or stress originated in, or initiated as action by, life in some form—his own, or some other. Now the supreme characteristic or concomitant of his own or of any other form of life, is breath, which like force or stress, is invisible; hence he reasons that force is breath, and conversely that breath is the force of life. He sees that this breath enters into and issues from every living being, and since every such being has distinctive form, he further reasons that every separate form, whether animate in our sense or not, has life of some kind or degree. He has, for example, no knowledge of air—as a gas—no knowledge of it other than as wind, and no conception of wind other than as breath, as the sort of something that he feels when he blows upon his hand and knows absolutely that he or his own breath is blowing, and that this breath it is that is coexistent with his mortal existence.

Therefore, he thinks not only of all forms as living, but also of the wind as necessarily the breath of some living form or being. And since his own little breath is so intimately of himself, he naturally imagines that this other greater breath must needs be as intimately that of some other and correspondingly greater and more powerful—what though invisible—being. He also imagines that this great being of the wind resides in the direction whence comes prevailingly its wind or its breath. Now when he observes that there are prevailing or distinctive winds of the diverse directions,—that of the north which blows hardest of them all and chiefly in winter; that of the west which blows more temperately and chiefly in spring time; that of the south, which blows softly and most frequently in summer; that of the east, which is again more fierce and chilly, and blows mostly in autumn; he not only severally locates these winds in their various quarters, but also differentiates them, and believes that the wind-being of the north produces cold and winter; of the west, moisture and spring; of the south, warmth, dryness and summer; of the east, coolness again, frost, and therewith the aging or maturing of all growing things, and autumn. And so to him the element of the north world is wind (or air, breath) preëminently; of the west world, water; of the south world, fire; and of the east world, earth or its seeds; and that each of these elements is produced by or is under the dominion of the special wind-god of its quarter; yet all combine, in the regular succession of the seasons, to make this World of the Middle what it is from year to year.

Now we shall see how this kind of belief comes to affect very directly the organizations, institutions and ceremonials (Shamanistic in particular) of primitive man, by examining into his mode of personifying the various gods or wind-monsters of the several quarters, and then of relating them to various divisions of his tribal communities. We have seen how he imagines that each one of these great world-breaths—productive as they are of effects so different—must proceed from beings of equally different character. How, therefore, he first not only locates these monster beings definitely in the several quarters of the world whence the winds or their breaths blow, but how also he imagines them to be beneficent or evil according to the various effects of their breaths, and then endows them with personalities corresponding to those of such of the animals especially characteristic of these several regions, as by their actions seem most closely to conform to these effects. The connection this has with the sociologic organization of the tribe may be explained without entering greatly into detail relative to the constitution of Indian society. You are all aware that the sociologic institutions of primitive peoples are almost universally Matriarchal, that is, are based upon *Clan* organization and mother descent. With them, each clan in the body politic is symbolized by some totem, animal or plant. Now since the various animals are supposed, according to their kinds, to be especially resident in one region or another, not only is there attributed to the Great Being or God of Wind in a particular region, a form more or less like to that of his supposed kind of animal therein, but also, the clans are organized with reference, in turn, to the supposed relation of their totems to these various animals and animistic or mythic beings of the special regions. And so, when, for example, a name is to be conferred upon a child of one of these totems, some process of divination must be entered into to determine what shall be his relation to the creatures and the deific being of one region or another, and correspondingly, of course, to his fellows among the clans. For it is held to be essential that this sacred relationship be symbolized, in some way or another, in the choice of his totemic name, and thus—as well as for many reasons into a consideration of which I cannot enter here—must be divined. Now in this process of divination, various instrumentalities are employed. For example, among the Zuñis, wands painted in diverse colors—each color being symbolic of a special region and plumed with appropriate bird feathers,—are sometimes set up in balls of clay, each placed out on the floor in the direction of the region to which the color of its wand relates it. Then it is noted which of the plumes waves most actively in any wind (or breath) that may be stirring. From this, the spiritual relation, so to say, or the source or totemic origin of the child is divined, and he will be named, and to a certain extent the course of his life will be determined upon according to this divination. For example, the Zuñi totem gods of the several regions are: the Gray Wolf for the East or Dawn-Land; the Mountain Lion or Puma for the North or fierce Winter-Land; the Black Bear for the Land of the West or Night; the sun-loving Badger for the South or Summer-Land; the Eagle for the Sky and Light, and the Burrowing Mole for the Under-Land and Darkness. Let us suppose that the plume on the white wand—the one that is set up toward the east—waves most actively; then, what though the child belong to a clan or totem of one of the other regions, he will nevertheless be regarded as *spiritually* related to the Gray Wolf of Dawn, and it will be believed by his fellows—and with their belief he will himself become, as he grows toward puberty, more and more impressed,—that he is destined for membership in the sacred organization or Shamanistic Society or Lodge of the Medicine-men of the East, or of the Wolf deity. Now when the age of puberty is attained, and the boy is to be solemnly invested with the garment or clout and the responsibilities of manhood, he is, as in the account quoted by Dr. Morris from Mr. Williams, required to pass through various ordeals, such as a period of vigorous fasting and purification (this both by means of emetics and purgatives); and to retire to some lonely spot and there keep, day and night, lengthy vigils, whereby it is sought to diminish for a time his earthly grossness interests and affections, to "still his heart" and quicken his spiritual perception and hearing of the meaning of the "Silent Surpassing Ones." This is in order that he may gain sign from or actually behold one of the Beings who wield, in the great quarters, the forces of nature, and who shall thereafter be his special Tamanawa or spiritual guide. It is also in order to aid him in seeking for some objective sign by which this relationship to his Genius may be proven to himself and made manifest to his people. In a condition of exaltation as he is—and I can attest to its absorbing nature, through having myself endured such an ordeal—you can well understand that his perceptions will become startlingly manifest in the various visions and signs he sees. These will seem to him, I can again personally assure you, far more real than the most absolutely actual things he has ever beheld or experienced. Perchance he gazes at the mist, or a cloud in the sky. The cloud will surely seem to take the form of a great gray wolf, and when he seeks for some token of that God of the Sky,—a tooth-like fossil, a few hairs maybe, which he may find on the ground nearby or underneath the apparition, will be reverently accepted as potent amulets, and he will bear them to the tribal Fathers or Shamans, and by them they will be received as a sign of his Genius, and he will be relegated to the phratral division or lodge of the Wolf. Or again, it may be that he will find a crystal, and because this crystal shines clearly and therein resembles the light by which we see and the eye through which we see—and hence is regarded as helpful in seeing—it will be regarded as a token of seership, as a sign of the Seeing Spirit, and fortunate the youth who is thus supposed to be endowed with the power of penetration into the unseen. To give yet one more example, let us suppose that he finds a concretion exhibiting spiral or concentric lines. He will regard this as a symbol of the Midmost itself, a token of his relation thereto also—no matter to what totem he may belong, or to what region he may be related by birth. For the spiral lines perceived in this crystal resemble those of the marks upon the sand produced by the whirling about of objects like red-topped grass by the whirlwind, yet which are regarded as the tracks of the whirlwind god, whose breath is the midmost of all the winds of the world.

Permit me to here give parenthetically a striking illustration of the way in which these primitive Shamans personify phenomena of nature, by instancing their personification of this god of the whirlwind. Of all the winds of heaven, the whirlwind alone is upright—progresses as man does, by *walking* over the plains. The whirlwind god is therefore endowed in part, with the personality of a man; but like the eagle, also, the whirlwind flies aloft and circles widely in the sky; therefore he is endowed with the wings and tail, the head, beak and talons of an eagle. Since the sand which he, the whirlwind, casts about, pricks the face as would minute arrows, the dreadful wings of the god are supposed to be flinty, and his character warlike or destructive, as is that of the eagle; yet of all the Beings of Wind, he is the most potent, for he twists about or banishes utterly from his trail, either the north wind or the south, the east wind or the west, and overcomes even gravity,—the pulling-breath of the earth or under world,—and therefore is the god of the midmost among all the six gods of wind. Thus, lucky in a purely practical way, is he who finds under given auspicious circumstances, his name-token in the shape of a little concentric concretion, for he will be in the line of ordination thereby, to the Central Council or Priesthood of his people.

And now I would fain add a word, another parenthetic statement, in amplification of what Dr. Morris has said in regard to the "Medicine-men," Priests or Shamans, of such primitive peoples,—in regard, that is, to their earnest character, to which I can fully testify.

I am aware that they are generally supposed to be mere quacks, charlatans or jugglers. I never knew one of them to be anything of the sort. Quite the contrary. I have lived among them in the tribe of my adoption, and was even initiated as one of their number, so far as was possible for one not born in the tribe, namely, into their Society of Warriors—"the *A'pithla Shi'wani*," or "Priesthood of the Bow"—and, moreover, I have been received in fraternal manner, by members of the priesthoods or medicine societies of other tribes. Now hardly a traveler among the Indians who does not come back and report what he thinks he saw when watching the operation of one of these medicine-men, but almost invariably his report is unreliable, from lack of understanding of what he saw. Let us take, for instance, the common account that is given of an Indian Medicine-Man endeavoring to effect a cure. It is said that he pretends to charm or to suck or rub forth a worm or a wasp or a grub or some other small object, from the diseased part of the man or woman he is treating. The traveler usually states that he saw the Medicine-Man, after going through his ceremonies, pretend to pluck out a wasp or grub or other object, and hold it up for the edification of the bystanders. A little thought in regard to what really occurs will explain all this. We all have our medical theories; so has the Indian Medicine-Man. Among the injuries the Indians are exposed to by their mode of living, a bruise from a stone or a hatchet would be, let us say, the most frequent. This bruise may fester and give rise to suppuration. The wound, naturally ill-cared for in their condition of life, would readily become offensive and breed maggots, which would batten on the sore. Now these people observe that decaying meat also produces maggots or "turns" to them, for, from their observation of countless slain animals, they believe that all flesh comes from, and returns to, worms. That the flesh may not be further destroyed, the Indian Medicine-Man will seek to exterminate these destructive worms; will seek for some other maggot which he will squeeze out in order that its form may so be fitted to absorb the invisible form of the infesting maggot; or else he will seek for some insect which preys upon maggots, like certain wasps, and will apply it to the infected place, using such aids as he can, by rubbing, scarifying, squeezing, sucking or blowing the diseased place, until he succeeds in forcing out the pus or black blood or serum and securing or snaring, as he supposes, the seed or occult creature of the ill. Then he will hold up the crushed grub or wasp, merely to show how successfully it has absorbed or fought and destroyed this disease-causing worm, but with no more thought whatsoever of chicanery, than a surgeon among ourselves would have in exhibiting a needle he had extracted from the hand or foot of his patient.

Now I have gone a long way around the subject in hand, in order to measurably substantiate my reasons for thinking that Dr. Morris is correct in his hypothesis as to the sacred and symbolic character and origin of the pentagonal dodecahedron which he has exhibited and commented upon here to-night. A figure even as elaborate and difficult of production in stone as is this, could readily have been formed by Indian artisans. Its shape might have been suggested in the process, perfectly familiar to them, of knapping a block or cube of stone, and afterwards breaking away its angles by battering, to form a sphere; or, better still, by the shapes of balls of clay—naturally formed round in the hands—and used as by the Zuñis in their processes of name—divination just described ; or again, by the shapes of pentagonal or other like—ever sacred—crystals. The scratchings or figures observed upon the various faces of this stone are quite such as might well have been drawn to differentiate them as being related to one region or another, and in all probability the figures thus scratched were further marked with pigments symbolic of the different regions, when this stone was used in such processes of divination. Close observation of the more distinct lines of these figures on the faces of the stone, shows that they were made by a flint point, not a metal instrument; for they are double,—that is within each one is a minute bead such as would be produced by the fracturing of a fine point of flint or other hard concoidal stone when drawn over the surface of another stone like this,—and not simply V-shaped as would have been the case had a metal instrument been used.

Some question may arise in the minds of those who have listened to Dr. Morris' paper, and to my comments thereon, as to the meaning of the twelve faces in this particular specimen; since, as I have explained there are only *six* regions, the north, west, south, east, upper and lower, that the midmost is at once surrounded by and contains within, itself. But I failed to say earlier and in the proper connection, that to the primitive-minded man, as there is no form without life, so there is no life-form, without due duality of origin —the father and the mother. Consequently we find that in relation to all things, (with tribes of primitive peoples like the Zuñis of to-day, and like the mound builders of long ago, who possessed and reverenced this object), the sexenary division is duplicated; but since there can be only one middle or content, the sexenary division is with them symbolized by the number seven, and when duplicated, we have, not fourteen, but thirteen; that is, six pairs which are visible, but only one for the concentric or synthetic middle, since there can be but one actual centre or middle to anything, even to the great world.

[Mr. Cushing stated, when a fuller revision of these notes was requested, that he would, at some future time, if the Society so desired, present instead a more comprehensive address on Shamanism in general.]

Stated Meeting, May 7, 1897.

The President, Mr. Fraley, in the Chair, assisted by Vice-President, Dr. Pepper.

Present, 68 members and about 100 visitors.

The Secretary presented the following correspondence:

A letter from Prof. James Glaisher, dated South Croydon, March 16, 1897, accepting membership.

A letter from the President announcing the appointment of the following members to prepare obituary notices of deceased members, viz.:

Dr. J. Cheston Morris, for Dr. Henry Hartshorne and Prof. H. D. Gregory.

Prof. Albert H. Smyth, for Prof. George Stuart.

Mr. Joseph C. Fraley, for Mr. Arthur Biddle.

Letters from Dr. J. Cheston Morris and Mr. Joseph C. Fraley, accepting their appointment as above.

A letter from Mr. Franklin Platt, resigning from the Special Committee of Geologists appointed April 2 to report on the rock specimens in the possession of the Society.

Dr. Pepper, on behalf of a number of members of the Society, presented an oil portrait of the late Prof. E. D. Cope.

On motion of Mr. Joseph C. Fraley, the gift was accepted and the thanks of the Society were given to the donors.

The Committee on the Phillips Prize Essay Fund reported the accompanying circular letter, announcing the proposed award of a prize.

PHILADELPHIA, 104 SOUTH FIFTH STREET, April 5, 1897.

The American Philosophical Society held at Philadelphia for Promoting Useful Knowledge has the honor to announce that an award of the Henry M. Phillips Prize will be made during the year 1899; essays for the same to be in the possession of the Society before the first day of May, 1899. The subject upon which essays are to be furnished by competitors is:

"*The development of the law, as illustrated by the decisions relating to the police power of the State.*"

The essay shall not contain more than one hundred thousand words, excluding notes. Such notes, if any, should be kept separate as an Appendix.

The Prize for the crowned essay will be two thousand dollars lawful gold coin of the United States, to be paid as soon as may be after the award. The Society invites attention to the regulations governing said prize, which accompany this circular.

WILLIAM V. MCKEAN,
CRAIG BIDDLE,
MAYER SULZBERGER,
C. STUART PATTERSON,
JOSEPH C. FRALEY,
AND
FREDERICK FRALEY, *President of the Society*, } *Ex-officiis*,
J. SERGEANT PRICE, *Treasurer of the Society*, }
} *Committee on the Henry M. Phillips Prize Essay Fund.*

The essays must be sent, addressed to Frederick Fraley, President of the American Philosophical Society, No. 104 South Fifth street, Philadelphia.

THE HENRY M. PHILLIPS PRIZE ESSAY FUND.

Miss Emily Phillips, of Philadelphia, a sister of the Hon. Henry M. Phillips, deceased, presented to the American Philosophical Society held at Philadelphia for Promoting Useful Knowledge the sum of five thousand dollars for the establishment and endowment of a Prize Fund, in memory of her deceased brother, who was an honored member of the Society. The Society accepted the gift and agreed to make suitable rules and regulations to carry out the wishes of the donor, and to discharge the duties confided to it. In furtherance whereof, among other rules and regulations adopted by the Society, are the following:

Competitors for the prize shall affix to their essays some motto or name (not the proper name of the author, however), and when the essay is forwarded to the Society it shall be accompanied by a sealed envelope, containing within, the proper name of the author, and, on the outside thereof, the motto or name adopted for the essay.

At a stated meeting of the Society, in pursuance of the advertisement, all essays received up to that time shall be referred to a Committee of Judges, to consist of five persons, who shall be selected by the Society from nomination of ten persons made by the Standing Committee on the Henry M. Phillips Prize Essay Fund.

Essays may be written in English, French, German, Dutch, Italian, Spanish or Latin; but, if in any language except English, must be accompanied by an English translation of the same.

No treatise or essay shall be entitled to compete for the prize that has been already published or printed, or for which the author has received already any prize, profit, or honor, of any nature whatsoever.

All essays must be *clearly* and *legibly* written or printed on one side of the paper only.

The literary property of such essays shall be in their authors, subject to the right of the Society to publish the crowned essay in its *Transactions* or *Proceedings*.

The Special Committee on Rock Specimens presented a report, recommending that all the specimens which have no labels, or designations by which they can be recognized, and which are not of value for other special reasons, be thrown away. Also that all specimens which can be recognized as to their locality, and are of any scientific value, be deposited in the collection of some institution, subject to recall, and a receipt taken therefor. The report was accepted, and the recommendation adopted.

Announcement was made of the decease of the following members:

Prof. Edson S. Bastin, on April 6, 1897, æt. 53.

Prof. Edward D. Cope, at Philadelphia, on April 12, 1897, æt. 56.

Dr. Traill Green, at Easton, Pa., on April 29, 1897, æt. 83.

Mr. George W. Biddle, at Philadelphia, on April 29, 1897, æt. 79.

The President was requested to appoint members to prepare biographical notices of Prof. Cope and Mr. Biddle.

The following papers were presented:

"Australian Rock Carvings," by R. H. Mathews.

"On the Transitive Substitution Groups that are simply Isomorphic to the Symmetric or the Alternating Group of Degree Six," by G. A. Miller, Ph.D.

Dr. Hays moved that after the presentation of Sir Archibald Geikie's communication, the meeting adjourn to reconvene on Thursday evening, May 13, at 8 o'clock. Adopted.

Sir Archibald Geikie then presented a verbal communication on "Recent Geological Work in the Hebrides and Faroe Isles," for which the best thanks of the Society were voted to him.

The meeting was then adjourned by the President, pursuant to the resolution previously adopted.

AUSTRALIAN ROCK CARVINGS.

(Plate IV.)

BY R. H. MATHEWS, L.S.

(Read May 7, 1897.)

At a meeting of the Royal Society of New South Wales, held on the 1st of August, 1894, I read a paper on "The Aboriginal Rock Carvings and Paintings" in that colony, for which I was awarded the Society's medal.[1] I also contributed papers on the same subject to the Anthropological Institute of Great Britain,[2] the Royal Society

[1] *Jour. Roy. Soc. N. S. Wales*, xxviii, 329, 330.

[2] *Jour. Anthrop. Inst.*, London, xxv, 145, 163.

of Victoria,[1] the Royal Geographical Society of Australia[2] and other learned bodies. Since then I have continued my researches, and have succeeded in discovering several other groups of native carvings not hitherto recorded, a description of which I have thought are worthy of being recorded.

In the papers above referred to I have described the way in which these carvings were executed by the native artists, their geographic range, etc., so that it will not be necessary in the following pages to again refer to these parts of the subject. The accompanying plate shows much the largest and most varied as well as the most valuable collection of rock carvings hitherto published. All the figures are drawn to scale from careful measurements and sketches taken by myself, and the position of each on the Government maps is also stated in the descriptions, so that they can readily be found by persons desirous of visiting them. As all the carvings are situated within New South Wales, it will not be necessary to add the name of the colony in the description of each figure.

Plate IV. Rock Carvings.

Fig. 1. This huge, roughly drawn figure of a man is carved on a table of Hawkesbury sandstone, almost level with the surface of the ground, on the old road from Peat's Ferry to Sydney, and is about half a mile northerly from Vize Trigonometrical Station, Parish of Cowan. The old dray track, now little used, passes over this figure, which has caused some of the lines to become rather indistinct.

From the feet to the top of the head measures ten feet eight inches.[3] Both eyes are shown and a diagonal line across the face. There is a line across the body at the waist, across each arm near the shoulder, across the left thigh, and the left ankle. An unfinished line rises from the left thigh, outside of the figure. The right hand and part of the left shoulder have been obliterated by the traffic along the road referred to.

Figs. 2, 3, 4 and 5. This group of carvings appears on a flat

[1] *Proc. Roy. Soc. Victoria*, vii (N. S.), 143, 156.

[2] *Proc. Roy. Geog. Soc. Aust.* (Q.), x, 46–70; *ibid*, xi, 86–105.

[3] For other gigantic carvings of men, the reader is referred to the following plates in various papers written by me on this subject: Figs. 1 and 6, Pl. 16, *Jour. Anthrop Inst.*, London, xxv, 145–163; Fig. 5, Pl. 2, *Proc. Roy. Geog. Soc. Aust.*, Queensland, xi, 86–105; and Fig. 7, Pl. 9, *Proc. Roy. Soc. Victoria*, vii (N. S.), 143–156.

sandstone rock, about a quarter of a mile in a northwesterly direction from Taber Trigonometrical Station, Parish of Broken Bay.

There are a man and a woman in the attitude of aboriginal dancers; the man is about four feet six inches high from his feet to his hands. The head contains eyes and mouth, but no nose, and there is a belt around the waist consisting of one incised line. On the upper side of the belt, and projecting from it, are two incised lines extending upwards about five inches. Lines are also cut across the arms above the shoulder, with short lines similar to those projecting from the belt extending a few inches along the centre of each arm. The hands have four fingers and the feet four toes each. The penis is shown in this figure by a single incised line,[1] instead of in the way usually found in native carvings.

On the right of the man is a female figure, much smaller, without eyes or mouth. The mammæ are depicted in the manner usually employed by the Australian aborigines in their paintings or carvings of women.[2]

Another carving, Fig. 4 in this group, represents a male figure, which is interesting on account of the lines rising from the head, which may represent hair, or may perhaps be intended for feathers or other ornaments stuck in the hair. The hands have four fingers only, and the feet have been carried away by the weathering of the rock.

On the same rock is another of those grotesque forms, Fig. 5, which are hard to definitely identify, and may be intended either for some kind of lizard or for a human being.

Fig. 6. The large sandstone rock containing this carving is distant from Taber Trigonometrical Station about fifteen chains in a westerly direction, Parish of Broken Bay. It is on the top of the range dividing Smith Creek from Coal and Candle Creek.

This shield is four feet five inches long by two feet broad, and has a longitudinal and a transverse subdivision. In the upper right-hand quarter are four jagged holes cut in the rock, and five similar holes in the lower right-hand quarter. The upper left-hand quarter of the shield contains five similar holes and the lower left-hand quarter six,

[1] Compare with Fig. 4, Pl. 2, of my paper on "Australian Rock Pictures," contributed to the Anthropological Society of Washington, and published in *The American Anthropologist*, viii, pp. 268–278.

[2] For an interesting carving of a woman dancing, see Fig. 3, Pl. 2, *American Anthropologist*, Vol. viii, pp. 268–278.

or twenty holes altogether. These holes are not in any symmetrical design, but appear scattered irregularly over the surface of the shield, and have probably been intended for ornamentation. The ethnological collection of the Australian Museum in Sydney contains a hielaman, or shield, from Queensland which has a longitudinal line and two median horizontal lines, and is ornamented with a groundwork of red dots. On the other hand, these marks may be intended to represent the indentations made by spears.

Near this shield is a hollow, or "pot-hole," in which water collects in wet weather. Around the margin of this small pool of water are a large number of grooves or hollows worn by the aborigines in sharpening their stone tomahawks. For illustrations and descriptions of similar grinding places, see my paper on "Some Stone Implements Used by the Aborigines of New South Wales," *Jour. Roy. Soc. N. S. Wales*, xxvii, pp. 301–305, Plate 43, Fig. 3.

Figs. 7–13. These carvings are all on the same flat rock, situated within Portion No. 1140, of forty acres, in the Parish of Manly Cove. The first three are apparently intended for eels, varying in length from four feet three inches to six feet one inch. Figs. 11 to 13 are all of the same kind of fish, but of different sizes. I am unable to say definitely what fish is intended to be represented, but it has been suggested perhaps that they are grupers. The length of the smallest is two feet four inches, and that of the largest four feet two inches.

Fig. 14. This drawing, which is on the same rock as Fig. 26, represents a man about five feet eight inches high, with a boomerang lying near him. The left hand has four fingers and the right five. The distance from the right toe to the centre of the boomerang is one foot two inches, the length of the latter being two feet four inches. The end of one of the weapons shown in Fig. 60 almost touches the right foot.

Fig. 15. This well-executed figure of a buck kangaroo is carved on a large flat rock of Hawkesbury sandstone, near the southern boundary of Portion No. 717 in the Parish of Manly Cove. The drawing appears to have been intended to represent the animal bent down in the attitude of grazing. The eye, one of the ears and the mouth are shown, the latter being open, which is unusual.

Figs. 16 and 17. These carvings are found on the perpendicular face of a large standstone rock about five yards from the left shore of Cowan Creek, about seven or eight chains above its confluence with Cockle Creek, in the Parish of Gordon. Fig. 16 represents a fish five feet nine inches long and about two feet nine inches across the body at the widest part. This fish has two eyes and three small dots about two feet three inches from the point of the nose, which are perhaps intended to represent gills. The tail is divided by two curved lines extending from the back to the belly. Within the outline of the larger fish there is a small one about eighteen inches long by eight and a half inches across the body. There are six representations of boomerangs, the most I have yet observed in so small a space, three of them being within the outline of the large fish, two partly within and one outside of the said outline.[1]

Ten feet five inches farther to the right from the nose of the large fish, on the vertical face of the same rock, are two small animals, Fig. 17, which are probably intended to represent kangaroo rats, judging by their size and general aspect.[2] They are each about one foot four inches in length, and are fairly well executed.

The side of the rock on which the figures are cut faces northeasterly, or towards Cowan Creek. These carvings are somewhat uncommon on account of being executed on the face of a vertical rock, such drawings being generally found on horizontal surfaces; they are, however, sometimes met with on rocks occupying different slopes between the two positions mentioned.

Fig. 18. This curious drawing is on the same flat rock as Fig. 26, and is probably intended to represent a fish, real or imaginary.[3] It is five feet three inches in length.

Fig. 19. This figure of a wallaby is on the eastern continuation of the same rock as Fig. 26, but is on the Government road separating Portions Nos. 1139 and 1140 before referred to. The length of the wallaby from the tip of the nose to the end of the tail is four feet five inches; it is in the attitude of jumping, and the eye is shown.

[1] Three feet seven inches to the left of the tail of the larger fish is the carving of an iguana six feet long which is shown as Fig. 11, Pl. 3, of my paper on "The Aboriginal Rock Pictures of Australia," *Proc. Roy. Geog. Soc. Aust.*, Queensland, Vol. x, pp. 46–70.

[2] Kangaroo-rats are represented in Figs. 13 and 14, Pl. 99, illustrating my paper on this subject in the *Report of the Australasian Association for the Advancement of Science*, Vol. vi, pp. 624–637.

[3] For other examples of nondescript or monstrous creatures drawn by the aborigines the reader is referred to Fig. 6, Pl. 2, *Proc. Roy. Geog. Soc. Aust.*, Queensland, Vol. xi, pp. 86–105; Fig. 10, Pl. 9, *Proc. Roy. Soc. Victoria*, Vol. vii (N. S.), pp. 143–156.

Fig. 20. This figure, which is three feet eleven inches high and on the same rock as Fig. 26, is probably intended to represent a boy. The correct number of fingers is shown on each hand.

Fig. 21. This remarkable carving is on a large, flat rock of Hawkesbury sandstone on the western side of the road from Pymble to Pittwater, within Portion No. 23 of 320 acres in the Parish of Narrabeen.

The drawing represents a man with a weapon in his left hand, which is raised over his head. It is not clear whether the weapon is a nullanulla or a tomahawk, resembling one as much as the other. This carving is one of unusual interest, as it shows what appears to have been intended for a breast on the left side, as if the native artist had at first intended to draw a figure of a woman and had afterwards changed his mind. Or it may have been drawn to represent a dilly bag carried by a string over the right shoulder, with the bag hanging under the left arm. Again, it may have been intended to show some deformity which existed in the man it was designed to represent; or perhaps the intention was to delineate some real or legendary personage having the characteristics of both sexes.

The head contains eyes, but no other features; the feet are drawn in the usual way, but the hands are not shown. From head to foot the man stands five feet eight inches high. The rock on which this figure is carved slopes gently towards the southwest, and the bearing of the figure from feet to head is N. 50° E.

Fig. 22. This figure of a man five feet eight inches high is on the same rock as Fig. 26. The eyes and mouth are shown, and the hands have each only four fingers.

Fig. 23. This figure of a woman, one foot seven inches high, is drawn on the same rock as the last described. The hands and feet are omitted, but the paps are shown as in other carvings of females delineated on this plate. This figure is interesting on account of the comparative smallness of its size.

Fig. 24. This figure of a man six feet high is on the same flat rock as Fig. 15. The fingers are shown on the right hand, but not on the left. On the left side of the head and coming partly within it is a shield one foot nine inches long and five inches wide, with a bar across it near the middle. The penis of this figure is drawn in an unusual style, showing the foreskin.

Fig. 25. This human figure is three feet three inches high, and although the sex is not shown I am inclined to think it is intended

to represent a young girl. I have arrived at this opinion by comparing it with Fig. 23 on the same rock and with Fig. 36 in a different locality. It may also be compared with Fig. 11 Plate 9, of my paper on "Aboriginal Rock Paintings and Carvings in N. S. Wales," published in the *Proceedings of the Royal Society of Victoria*, vii, N. S., pp. 143–156.

Fig. 26. This carving is delineated on a flat rock of Hawkesbury sandstone sloping northerly, within Portion No. 1139 of twenty-four and one-half acres in the Parish of Manly Cove. This drawing is apparently intended to represent the wombat, an Australian animal with a very short tail and heavy body. Like many other native drawings, the animal is shown much larger than the natural size. From the point of the nose to the end of the tail it measures nine feet eight inches, and across the body at the widest part it is four feet. The plate shows the figure exactly as it appears upon the rock, the usual careful measurements having been taken. Within the outline of this carving is what appears to be a snake three feet six inches long.[1]

Fig. 27. This carving, which probably represents a shark,[2] is on the same rock as Fig. 26, and is eleven feet long. There are two dorsal and one ventral fin and a fairly good tail. The nose of this fish is very pointed, a peculiarity I have observed in other native drawings. Near the mouth is a boomerang one foot eight inches long, on the concave side of which is a small oval figure. Farther on towards the tail of the fish are two other oval figures of larger size, but I am at present unable to suggest what they are intended to represent—they might conceivably be meant for eggs.

Fig. 28. This figure is on the same rock as Fig. 61, and represents a man four feet four inches high. Contiguous to his right hand are two oval figures about a foot long and nine inches across, which may have been intended to represent shields, or possibly the eggs of a bird. A similar object is shown in Fig. 61.

Fig. 29. This group of carvings is situated on the horizontal surface of several large tabular masses of Hawkesbury sandstone, all in

[1] This carving is shown as Fig. 14, Pl. 3, in my paper on "The Aboriginal Rock Pictures of Australia," in *Proc. Roy. Geog. Soc. Aust.*, Qld. Bch., Vol. x, pp. 46–70.

[2] An immense fish carved on a rock by the aborigines is shown in Fig. 15, Pl. in my paper on "Aboriginal Rock Paintings and Carvings in N. S. Wales," published in *Proc. Roy. Soc. Victoria*, Vol. vii (N. S.), pp. 143–156.

close proximity to each other on the western side of the cleared road leading from Pymble along the dividing range between Cowan and Cockle Creeks, about half a mile southerly from "Bobbin" Trigonometrical Station, in the Parish of Gordon.[1]

The largest emu[2] is six feet three inches from the beak to the end of the tail, and is five feet high, in the attitude of looking for food or at something on the ground; and although the neck is rather too short, it is a very fair picture of an emu. Only one leg is delineated, and the foot is shown in continuation of the leg.

The other emu, which is much smaller, measures three feet two inches from the beak to the tail, and stands three feet five inches high. In this drawing the eye has been added, and one leg with its foot is delineated in the same way as that of the large emu.

Between the last two birds is a small one, fifteen inches from tail to head, and fourteen inches from pinion to pinion. Were it not for the presence of wings and the shortness of the neck and legs we might suppose this to be intended for a young emu to complete the picture. As it is, however, it appears to represent some bird upon the wing.

Fig. 30. This carving is also on the continuation of the same flat rock which contains Fig. 29. The figure measures two feet four inches in extreme length, one foot two inches across the fore feet and one foot four inches across the hind feet. The head is four inches long and the tail nine inches. This drawing appears to be intended for a flying squirrel, as it resembles that animal more

[1]Besides Figs. 29 to 37, inclusive, shown in this plate and now described, there are on the same cluster of rocks some other carvings which are described by me elsewhere, the positions of which are as follows: About five paces from the snout of Fig. 31 is a group representing a man and woman in the attitude of dancing. Near them is a native "dilly bag" and several human footmarks cut into the rock. For a description of this group of carvings see my paper on "Aboriginal Rock Paintings and Carvings in N. S. Wales," published in *Proc. Roy. Soc. Victoria*, Vol. vii (N. S.), pp. 143–156, Pl. 9, Fig. 8.

About twenty-five or thirty paces in a southwesterly direction from the last-mentioned carvings is another group representing two men and two emus. For a drawing of this group, see Fig. 3, Pl. 2, in my paper on the "Rock Pictures of the Australian Aborigines," published in the *Proceedings of the Royal Geographical Society of Australasia*, Queensland, Vol. xi, pp. 86–105.

[2]A group of six emus are represented in Fig. 1, Pl. 2, in my paper on "Australian Rock Pictures," published in *The American Anthropologist*, viii, 268–278.

closely than any other I can compare it with. It may, however, be intended to represent some bird.

Fig. 31. This figure is delineated on the same flat rock of Hawkesbury sandstone as Fig. 29. It measures four feet five inches from the point of the nose to the tip of the tail; the head contains an eye, and there is also a dot on the ear, apparently to indicate the hollow part of it. I submit that this is intended to represent an opossum,[1] because the portion of the body is more horizontal than in figures of kangaroos and kangaroo-rats, in which the fore part of the body is always more or less elevated. The position of the tail, pointing slightly upwards, also strengthens the supposition that it is an opossum.

Fig. 32. This carving is on a flat rock of Hawkesbury sandstone, not far from the last-described carving, and appears to be intended to delineate a bird on the wing,[2] but it is difficult to suggest what bird is the likeliest to be indicated, and in trying to arrive at a definite conclusion the forked tail should not be lost sight of. From the extremity of one wing to that of the other measures three feet, and the total length from the head to the end of the tail is one foot eleven inches. It is well known that the natives had animals and birds as totems; among these may be mentioned the eagle hawk, the crow, the white cockatoo, the emu, the kangaroo and so on.

Fig. 33. This peculiar carving is executed on the same group of flat rocks as the preceding, and delineates the lower part of the body of a man, from the waist downwards, the knees being bent outwards, with the feet also in the same direction. From the outside of one knee to the outside of the other measures three feet eight inches. The figure may have been intended to indicate that the man was sitting on the rock, the rest of the body being upright and not shown; or perhaps it was intended to convey the idea that the rest of the man's body had gone into the rock, leaving this part protruding. I have seen similar figures carved upon rocks, but they are uncommon,[3]

[1] For another carving of an opossum see Fig. 7, Pl. 3, *Proc. Roy. Geog. Soc. Aust.*, Queensland, p. 67.

[2] For carvings of birds on the wing the reader is referred to Fig. 2, Pl. 99, illustrating my paper on "Rock Paintings and Carvings of the Aborigines of New South Wales," published in the *Report of the Australasian Association for the Advancement of Science*, Vol. vi, pp. 624–637.

[3] For a similar carving see Fig. 10, Pl. 2, attached to my paper on "Rock Pictures of the Australian Aborigines," *Proc. Roy. Geog. Soc. Aust.*, Queensland, Vol. xi, pp. 86–105.

Fig. 34. This small figure is also on the same line of rocks as Fig. 31. It is one foot seven inches high, and the same distance from hand to hand. The head is rather bird-shaped, and has an eye; there are incised curved lines reaching from the arms to the head on each side, the meaning of which I am unable to suggest.

This figure is most likely intended to denote a "piccaninny" or young aborigine, because there was room on the rock to draw a much larger figure if it had been desired. We frequently, I might say mostly, find figures of men drawn in caves which are not larger than this, but in such cases the small-sized figures are chosen on account of want of room on the cave walls.[1]

Fig. 35. This carving is on a continuation of the same flat rock as Fig. 31 and is another of those objects found in aboriginal drawings the precise identity of which it is difficult to arrive at. It is probably intended for the echidna[2] or porcupine, but I would, however, throw out the suggestion that it may be intended to represent a dilly bag. Some color is lent to this view from the lines drawn across it; the dot, which may represent the eye, is, however, against the latter theory.

Fig. 36. This carving is delineated on the continuation of the same flat rocks as the preceding, and represents a female two feet seven inches high and about the same distance across from hand to hand.[3] The arms are very long for the size of the body, and there are four fingers on each hand, but the feet are not shown. In the centre of the head is a small hole or dot, and there are two similar holes on the chest, but whether they were put there by the native artist or are merely water-worn indentations in the rock is uncertain. Above the figure there is a bird-like object which at the nearest points is two and a half inches from the head. This may be intended as an ornament to the head, or it may be where some other figure has been commenced and abandoned. The breasts are drawn in the usual way adopted by native artists, and there is a short incised line apparently intended to represent the *pubes*.

[1] A few feet from this figure is a carving of an iguana seven feet two inches long, shown as Fig. 9, Pl. 9, *Proc. Roy. Soc. Victoria*, Vol. vii (N. S.), p. 153.

[2] For similar carvings see Figs. 11 to 17, Pl. 2, *American Anthropologist*, viii, 276.

[3] For a colossal carving of a woman nearly twelve feet tall, the reader is referred to Fig. 2, Pl. 16, of my paper on "The Rock Paintings and Carvings of the Australian Aborigines," *Jour. Anthrop. Inst.*, London, Vol. xxv, pp. 145–163.

Fig. 37. This carving is also on the same flat rocks as Fig. 31. It is evidently intended to represent a male, probably a youth. It has the same bird-like head as Fig. 34, a form not uncommon in native carvings. The legs are short, but the termination of them is well defined, showing that they were originally drawn as they now appear. Near the extremity of one of the legs is a small unfinished drawing eight inches long by two inches wide.

Fig. 38. This large fish, apparently intended for a shark, is delineated on the same rock as Fig. 15; it is fourteen feet four inches long and three feet nine inches across the widest part of the body, not including the fins. It has a pointed nose like Fig. 27 and otherwise closely resembles that fish.[1]

Fig. 40. This interesting carving is delineated on the same rock on which Fig. 26 appears and represents a fish two feet nine inches long and one foot across the body at the widest part. It has a dorsal and a ventral fin and a small, well-formed tail. An incised line, similar to that marking the outline of the fish, extends from its mouth for about five feet six inches along the rock.[2] This is evidently intended as the picture of a fish caught on a line.[3]

Fig. 41 consists of a circular figure with a winding lind extending from it to another figure one foot six inches long and six inches wide. Within the former is one of those oval objects referred to in Fig. 27. Both this and the preceding carving, Fig. 40, are on the same flat rock as Fig. 26.

Figs. 39, 42 and 43. Fig. 43 I am unable to offer any explanation of at present. Fig. 39 are no doubt intended either for human hands or the paws of some animal.[4] The upper one has three fingers, the lower one four, each having a thumb in addition. Fig. 42 is, in my opinion, a human hand with part of the arm attached, and not

[1] The reader is referred to my paper on "The Rock Paintings and Carvings of the Australian Aborigines," *Journ. Anthrop. Inst.*, xxv, pp. 145–163, Pl. 16, Fig. 7, for a carving of a very large shark, 33 feet 10 inches in length.

[2] For a similar carving of a fish caught on a line see Fig. 13, Pl. 2, illustrating my paper on "The Rock Pictures of the Australian Aborigines," *Proc. Roy. Geog. Soc. Aust.*, Queensland, Vol. xi, pp. 86–105.

[3] Collins says he saw the natives of New South Wales fishing with a hook and line. The line was made of the bark of a small tree, and the hooks of the pearl oyster shell, which they rubbed on a stone until it assumed the shape desired.—*Account of the English Colony in N. S. Wales*, 1798, Vol. i, pp. 556–557.

[4] For a similar hand see Fig. 1 (g), Pl. 2, *Proc. Roy. Geog. Soc. Aust.*, Queensland, Vol. xi, pp. 86–105.

a foot, as might be supposed at first sight. Compare with representations of feet in Fig. 61.

Figs. 44 to 47. On the same rock as Fig. 26 are representations of fish of different sizes, ranging in length from two feet two inches to six feet. Six inches from the mouth of Fig. 45 are two lines crossing each other, one being ten inches long, the other five.

Fig. 48. This figure of a man five feet nine inches high appears on the same rock as Fig. 61 and is close to it. The eyes, mouth, and the proper number of fingers are delineated, as well as a belt round the waist. A small oval figure, similar to those seen in Fig. 27, appears close to the belt on the right-hand side.

Fig. 49. This appears to me to be part of a shield, which was left when half finished. It is two feet five inches long and ten inches wide. It is on the same rock as Fig. 47 and is close to it.

Fig. 50. This interesting drawing of a fish four feet six inches long appears on the same flat rock as Fig. 15. There are two dots for the eyes, on the same side of the head, a peculiarity of native drawing frequently seen in representations of fish.

Fig. 51 is on the same rock as the preceding, and is a very good drawing of a fish four feet five inches long.

Fig. 52 represents a shield three feet six inches long and one foot eight inches wide, and is on the same rock as the last two figures. Attention is drawn to the unusual point at the end.

Fig. 53. This figure represents a shield four feet three inches in length and one foot nine inches in breadth, with a longitudinal and a transverse subdivision. This carving is on the same series of flat rocks as Figs. 7 to 13 and is not far from them.

Fig. 54. This drawing, which is on the same rock as Fig. 26, may have been intended to represent a fish, or perhaps the skin of some animal.

Fig. 55 is on the same rock as Fig. 26, and represents a human figure five feet one inch high, the sex of which is uncertain. Five fingers are shown on each hand.

Figs. 56 and 57. Fig. 56, which is eighteen inches long, is apparently intended to represent the native tomahawk, with handle attached. Fig. 57, which is one foot nine inches long, may be either a nulla nulla or a tomahawk. These figures are carved on a mass of Hawkesburg sandstone more than an acre in extent, about five chains from the eastern side of the old road from Peat's Ferry to Sydney, and about a mile northerly from the rock containing Fig. 1.

Fig. 58. This large fish is carved on the same mass of sandstone as Fig. 1, but several yards farther south, and close to the old dray track. It measures twenty feet five inches from the snout to the farthest end of the tail, and thirteen feet from point to point of the fins. Across the larger of the fins, which appears to be the dorsal, is an incised line, such as is frequently met with on the bodies of different animals drawn by the aborigines. The two eyes are shown on the same side of the head, a mode of representing the eyes often observed in native pictures. The greatest width of the body, independently of the fins, is eight feet.[1]

Fig. 59. This representation of an eel is three feet four inches long, and five inches across the widest part of the body; from point to point of the fins measures seven inches. There are four bands or lines across the body. It is carved on the same flat rock as Figs. 56 and 57. For other carvings of eels, see Figs. 7, 8 and 9 of this plate.

Fig. 60. It is difficult to arrive at a definite conclusion as to what these figures are intended to represent. One is ten feet long, the other twelve, and they each have an average width of three inches. They occupy a position on the rock very close to Fig. 14, the end of them almost touching the right foot of the latter. Perhaps they represent spears or yamsticks; or were possibly intended for large snakes.

Fig. 61. This interesting carving is on a flat rock of Hawkesbury sandstone with Portion No. 796 of 9 ac. 2 r. 3 p., Parish of Manly Cove. It represents a man six feet high, with a belt round the waist and bands round the arms near the shoulder, similar to those seen in Fig. 1. Within the outline of the body is a very good representation of a human foot, twelve inches long, four inches across the toes, and three inches across the heel.[2] About three feet behind the heel of the last-mentioned figure is another human foot, not so perfect as the first, twelve inches long and having only four toes. Eleven inches farther away in the same direc-

[1] For a monstrous carving of a shark, nearly thirty-nine feet long, see my paper on "The Rock Paintings and Carvings of the Aborigines of N. S. Wales," published in *Rep. Australas. Assoc. Adv. Sci.*, vi, pp. 624–637, Pl. 99, Fig. 30.

[2] Human footmarks carved on rocks are represented in Fig. 8, Pl. 9, illustrating my paper on "Aboriginal Rock Paintings and Carvings in New South Wales," published in the *Proceedings of the Royal Society of Victoria*, Vol. vii (N. S.), pp. 143–156.

tion is an oval object, but what it is intended to represent I am at present unable to offer an explanation. The two last-described figures are shown in their relative positions to each other, but are not so in reference to the man. They are shown above the head of the latter on the plate to fill out a vacant space, but a careful reading of this description will indicate their true position.

ON THE TRANSITIVE SUBSTITUTION GROUPS THAT ARE SIMPLY ISOMORPHIC TO THE SYMMETRIC OR THE ALTERNATING GROUP OF DEGREE SIX.

BY G. A. MILLER, PH.D.

(Read May 7, 1897.)

When the degree of a symmetric or an alternating group is not 6 we can obtain all the simple isomorphisms of the group to itself by transforming it by means of the substitutions of the symmetric group of the same degree. In other words, we can construct only one intransitive group of degree mn and order n ! or n ! ÷ 2, whose m transitive constituents are respectively the symmetric or the alternating group of degree n, $n \mp 6$.[1] Hence the number of transitive substitution groups that are simply isomorphic to the symmetric group of degree n ($n \pm 6$) is equal to the total number of substitution groups (transitive and intransitive) that can be constructed with n letters and whose order is less than n ! ÷ 2, while the number of those that are simply isomorphic to the alternating group of this degree is equal to the number of all the other positive groups that can be constructed with n letters.[2]

As nearly all the groups that can be constructed with n letters are subgroups of larger groups that do not involve the symmetric or the alternating group of degree n and whose degree $< n + 1$, the transitive substitution groups that are simply isomorphic to the

[1] Hölder, *Mathematische Annalen*, Vol. xlvi, pp. 340, 345; cf. Miller, *Bulletin of the American Mathematical Society* (1895), Vol. i, p. 258.

[2] Dyck, *Mathematische Annalen*, Vol. xxii, p. 90; cf. Miller, *Philosophical Magazine* (1897), Vol. xliii, p. 117.

symmetric or the alternating group of degree n are, as a rule, non-primitive.[1] Those that are simply isomorphic to the alternating group are simple when $n \mp 4$ and can therefore contain no substitution besides identity that leaves all of their systems of non-primitivity unchanged. The first group of this kind is of order 60 and degree 12. Its elements can be divided in only one way so that each division is a system of non-primitivity. Even when such a group has different sets of systems of non-primitivity it cannot contain any substitution besides identity that leaves all the systems of non-primitivity of any set unchanged since it contains no self-conjugate subgroup except identity.

The following well-known group illustrates that the elements of some non-primitive groups can be divided into different sets of systems of non-primitivity, so that the groups contain no substitution besides identity that leaves all the systems of one set unchanged while they contain other substitutions that leave those of another set unchanged.

1	ad. bf. ce
abc. def	ae. bd. cf
acb. dfe	af. be. cd

This group contains no substitution besides identity that leaves all the systems of non-primitivity of any one of the following three sets unchanged ;

a,d : b,e : c,f   a,e : b,f : c,d   a,f : b,d : c,e

while three of its substitutions leave the systems of the following set unchanged ;

a,b,c : d,e,f.

The other regular group of order 6 may serve to illustrate that the elements of some non-primitive groups cannot be divided into systems of non-primitivity so that the groups contain no substitution besides identity that leaves all the systems unchanged.

A non-primitive group that is simply isomorphic to the symmetric group of degree n ($n \mp 4$) contains only one selfconjugate subgroup besides identity. If its largest subgroup whose degree is less than the degree of the group corresponds to a positive subgroup of the symmetric group, its selfconjugate subgroup must be intransitive and it must have two systems of non-primitivity. If the given sub-

[1] Cf. Maillet, *Comptes Rendus*, Vol. cxix, p. 362.

group corresponds to a positive and negative subgroup of the symmetric group the selfconjugate subgroup of order n ! ÷ 2 is transitive, and the non-primitive group contains no substitution besides identity that leaves all the systems of any of the possible sets of systems of non-primitivity unchanged. We thus obtain composite non-primitive groups that do not contain any substitution besides identity that leaves all the systems of any of the possible sets of systems of non-primitivity unchanged. The first group of this kind is of order 120 and degree 15.

Both the symmetric and the alternating group of degree 6 contain 6 ! simple isomorphisms to themselves that cannot be obtained by transforming the groups by means of any substitutions whatever. If we regard these groups as operation groups of orders 6 ! and 6 ! ÷ 2 respectively we can find an operation group of order 2 × 6 ! which transforms both of them into all the possible simple isomorphisms to themselves.[1] This group is simply isomorphic to the group of all simple isomorphisms of the given operation groups to themselves and contains the symmetric group of order 6 ! as selfconjugate subgroup.

That the smallest operation group which transforms a given operation group into all the possible simple isomorphisms to itself is always simply isomorphic to the group of all these simple isomorphisms may be easily proved as follows. We represent the given operation group of order g by the regular substitution group. The largest group of degree g that contains it as a selfconjugate subgroup transforms it into all the possible simple isomorphisms to itself and has a g, 1 correspondence[2] to the group of these simple isomorphisms. Its subgroup which contains all the substitutions that do not involve one of its g elements must be simply isomorphic to the group of all the given simple isomorphisms since all the substitutions that are commutative to each of the substitutions of the given regular group form a regular group of degree g.

It is known that the symmetric or the alternating group of degree 6 can be made simply isomorphic to itself by placing the group of order 120 or 60 and degree 6 in correspondence to a group of degree 5. All the substitutions of order 3 in such a 1, 1 correspondence are of degree 9, for it is evident that some are of this degree and that all must have the same degree because all the subgroups of

[1] Cf. Frobenius, *Sitzungsberichte der Akademie zu Berlin*, 1895, p. 184.

[2] Jordan, *Traite des Substitutions*, p. 60.

order and degree 3 as well as those of order 3 and degree 6 are conjugate in the symmetric and in the alternating group. From this it follows that the substitutions of degree and order 2 must correspond to those of degree 6, and hence that all the substitutions of order 2 in such a 1, 1 correspondence are of degree 8.

The Fifteen Transitive Substitution Groups that are Simply Isomorphic to (abcdef) pos.

We shall consider these groups in the order of their degrees, beginning with those of the highest degrees. There is one group of degree 360, viz., the regular group. We represent it by G_1. As there is only one positive group of order[1] 2 and the two groups of order 3 can be made to correspond there is one transitive group (G_2) of degree 180 and one (G_3) of degree 120 that are simply isomorphic to (abcdef) pos. Since the given group of order 2 is transformed into itself by 8 positive substitutions and the given groups of order 3 are transformed into themselves by 18 positive substitutions G_2 and G_3 are respectively of class[2] 176 and 114.

There is only one positive cyclical group of order 4 and the two positive non-cyclical groups of this order can be made to correspond since the transitive one cannot occur in $(abcde)_{10}$, and hence it can also not occur in $(abcdef)_{60}$. The group (G_4) of degree 90 whose 4 substitutions that do not contain a given element form a cyclical group is of class 88 since there are only 8 positive substitutions that transform the given positive group of order 4, or its subgroup of order 2, into itself. The other group of this degree (G_5) is of class 84. In both of these groups, the subgroup which contains the four substitutions that do not involve a given element contains three substitutions of the same degree. Since there is only one group of order 5 there is only one group of degree 72 (G_6) that is simply isomorphic to (abcdef) pos. It is of class 70.

Since only one of the two positive groups of order 6 is found in (abcde) pos., they can be placed in correspondence and there is only one transitive group (G_7) of degrce 60 that is simply to (abcdef)

[1] We consider only those groups whose degree does not exceed 6. A list of these groups is given by Prof. Cayley, *Quarterly Journal of Mathematics*, Vol. xxv, p. 71.

[2] The class of a substitution group is the degree of its substitution that permutes the smallest number of elements besides identity. Cf. Jordan, *Liouville's Journal*, 1871.

pos. We proceed to find the forms of the substitutions of the subgroup of G_7, which contains all its substitutions that do not involve a given element. Its substitutions of order 3 clearly consist of 19 distinct cycles of degree 3. If we arrange the substitutions of (abcdef) pos., according to [(abc) all (de)] pos., or (abc. def) all, we obtain 4 rows of substitutions whose — 1 powers transform any one of the substitutions of order two in either of these groups into substitutions of the same group. Hence the corresponding substitution of G_7 is of degree 56, and this is also the class of G_7. Its subgroup which includes the substitutions that do not involve a given element contains therefore 2 substitutions of order 3 and degree 57, 3 of order 2 and degree 56, and identity.

Since there is only one positive group of each of the orders 8, 9, 10 there is only one transitive group of each of the degrees 45, 40, 36 that is simply to (abcdef) pos. We shall denote these groups by G_8, G_9, G_{10}. Their classes are respectively 40, 36, 32. The two positive groups of order 12 lead to only one group (G_{11}) since one of them occurs in (abcde) pos. and its substitutions of order 3 are also of degree 3. G_{11} is of degree 30 and class 24. Half of its substitutions of order 3 are of degree 30 and the rest of degree 24. All its substitutions of order 2 are of degree 28. There can be only one transitive group of degree 20 (G_{12}) that is simply isomorphic to (abcdef) pos. since there is only one positive group of order 18. All of its 80 substitutions of order 3 are of degree 18 and its 45 substitutions of order 2 are of degree 16. As the other substitutions are of degree 20 G_{12} is of class 16.

There can be only one transitive group of degree 15 (G_{13}) that is simply isomorphic to (abcdef) pos. since the two positive groups of order 24 must evidently correspond in the simple isomorphism of (abcdef) pos. to itself in which all the substitutions of order 3 are of degree 9. G_{13} contains the following substitutions, besides identity, whose degrees are less than 15: 40 of order 3 and degree 12, 45 of order 2 and degree 12, 90 of order 4 and degree 14. Hence it is of class 12. The group of degree 10 (G_{14}) that depends upon the positive group of order 36 contains 90 substitutions of order 3 and degree 9, 45 of order 2 and degree 8, 90 of order 4 and degree 8. The rest are of degree 10 with the exception of identity. The group (G_{15}) which depends upon either of the two groups of order 60 is (abcdef) pos. itself.

Since each of the three groups

(abcde) pos. (abcdef)$_{36}$ [(abcd) all (ef)] pos.

is a maximal subgroup of (abcdef) pos. the corresponding groups, viz., G_{15}, G_{14}, G_{13} are primitive. The other 12 are non-primitive. As they are simple groups they cannot contain any substitution besides identity that leaves all the systems of non-primitivity unpermuted. If we arrange the substitutions of (abcdef) pos. according to (abcde) pos. we may letter the rows in such a manner that they are permuted according to a substitution that is identical to the particular substitution into which the entire group is multiplied. This is clearly not the case when they are arranged according to (abcdef)$_{60.}$ since the necessary and sufficient condition that a given substitution leads to a substitution whose degree is less than the degree of the simply isomorphic transitive group is that it is conjugate to some substitution in the group which forms the first row. G_{13} is simply transitive since its order is not divisible by 14. G_{14} and G_{15} are clearly multiply transitive.

The Thirty-five Transitive Substitution Groups that are Simply Isomorphic to (abcdef) all.

The subgroups which correspond in a simple isomorphism of (abcdef) pos. to itself correspond also in some simple isomorphism of (abcdef) all to itself. Hence each group that leads to a transitive group of degree n that is simply isomorphic to (abcdef) pos. leads also to a transitive group of degree 2n that is simply isomorphic to (abcdef) all. We observed above that the latter groups contained two systems of non-primitivity and that they are the only groups which are simply isomorphic to (abcdef) all and have this property. Hence 15 of the non-primitive groups that are simply isomorphic to the symmetric group of degree 6 contain two systems of non-primitivity. Their degrees are as follows:

720, 360, 240, 180, 180, 144, 120, 90, 80, 72, 60, 40, 30, 20, 12.

The remaining 20 transitive groups that are simply isomorphic to (abcdef) all depend upon subgroups that involve negative substitutions. We shall therefore confine our attention to such subgroups. As the methods are similar to those employed in what precedes we shall be more brief in our explanations. The two groups of order 2 lead to the same transitive group (G_{16}) since all the substitutions of order 2 in some of the simple isomorphisms of (abcdef) all to itself are of degree 8, as observed above. G_{16} is of degree 360 and class 336.

The two groups of order 4

$$(ab)\ (cd) \qquad [(abcd)_4\ (ef)]\ \text{dim.}$$

must correspond in some of the simple isomorphisms of (abcdef) all to itself for the reason just given. They therefore lead to the same group of degree 180 (G_{17}). Since the largest group that transforms (ab. cd) (ef) into itself must also transform each of its substitutions into itself this group could not correspond to either of the preceding groups in any of the given isomorphisms. It therefore leads to a different group of degree 180 (G_{18}). It is evident that (abcd) cyc. leads to another group of this degree (G_{19}). The two cyclical as well as the two non-cyclical groups of order 6 must correspond in the simple isomorphism of (abcdef) all to itself in which the substitutions of order 3 are of degree 9. Hence these lead to only two groups of degree 120 (G_{20}, G_{21}).

The two groups of order 8 which contain no substitution whose order exceeds 2 must correspond in the isomorphisms in which the substitutions of order 2 are of degree 8. Hence they lead to the same group of degree 90 (G_{22}). In the same isomorphisms $(abcd)_8$ must correspond to $[(abcd)_8\ (ef)]$ dim. with respect to (abcd) cyc. We represent the group which depends upon either of these two groups by G_{23}. Each of the remaining two groups of order 8

$$(abcd)\ \text{cyc.}\ (ef),\ [(abcd)_8\ (ef)]\ \text{dimidiated with respect to}\ (ab)\ (cd)$$

leads to a transitive group of degree 90 that is simply isomorphic to (abcdef) all. We represent these two groups by G_{24} and G_{25} respectively. The former of the given groups of order 8 is the only one that is commutative and contains operations of order 4 and the latter is the only one that is non-commutative and contains operations of order 4 and degree 6. On account of these properties each of these groups must correspond to itself in all the possible simple isomorphisms of (abcdef) all to itself.

The two groups of order 12 must correspond in some of these simple isomorphisms since the substitutions of order 3 are of degree 3 in the one and of degree 6 in the other. Hence they lead to the same group of degree 60 (G_{26}). As there is only one group of order 16 there is only one group of degree 45 (G_{27}). Since the subgroups of degree 6 and order 3 in $(abcdef)_{18}$ are self-conjugate while those of degree and order 3 are conjugate, this group must correspond to the other group of order 18 in the isomorphism in which all the substitutions of order 3 are of degree 9. Hence there is only one group of degree 40 (G_{28}). The single group of order 20 leads to a group of degree 36 (G_{29}). It is evident that (abcd) all and $(\pm\ abcdef)_{24}$ as well as (abcd) pos. (ef) and $(abcdef)_{24}$, lead to the same group. These two groups (G_{30} and G_{31}) are of degree 30.

The transitive and the intransitive group of order 36 lead to the same group of degree 20 (G_{32}) for the same reason as was employed to show that the transitive and the intransitive group of order 18 lead to the same group. The groups which we employed so far are non-maximal subgroups of (abcdef) all. Hence each of the 32 groups given above is non-primitive. Only the first fifteen of them contain substitutions which leave all the systems of non-primitivity unchanged. It remains to find the three primitive groups that are simply isomorphic to (abcdef) all.

The one of the highest degree (G_{33}) depends upon either one of the following groups

$$(abcdef)_{48} \qquad (abcd)\ \text{all}\ (ef)$$

It is therefore of degree 15. The next (G_{34}) depends upon the single group of order 72 and hence is of degree 10. The last (G_{35}) depends upon (abcde) pos. or upon $(abcdef)_{120}$. This is (abcdef) all itself. G_{33} is simply transitive since its order is not divisible by 14. As it contains 48 substitutions that transform each of the 7 substitutions of the form ab. cd. ef. contained in $(abcdef)_{48}$ into itself it is of class 8. We have already observed that the self-conjugate subgroups of G_{34} and G_{35} are multiply transitive, hence the groups themselves must be multiply transitive. Their classes are 6 and 2 respectively.

Paris, April, 1897.

Adjourned Stated Meeting, May 13, 1897.

The Treasurer, Mr. Price, in the Chair.

Present, 19 members.

The following papers were read :

"On the Geology of the Paleozoic Area of Arkansas South of the Novaculite Region," by George H. Ashley, Ph.D., with an Introduction by John C. Branner, was read by title.

"Stellar Dynamics," by Mr. Luigi D'Auria.

A letter was read from the Biological Faculty of the University of Pennsylvania, asking the Society to appoint a representative of this Society to make provision for a meeting memorial of the late Prof. E. D. Cope, and the President of the Society was requested to appoint such a representative.

Prof. Doolittle moved "that a Committee of five, consisting of Dr. Pepper, Hon. George F. Edmunds, Dr. Persifor Frazer, Dr. T. Hewson Bache and Hon. H. A. DuPont be appointed to consider and report to the American Philosophical Society on the matter of a Franklin Memorial to celebrate the Bicentennial Anniversary of Benjamin Franklin's birth, in 1906." Adopted.

A letter from the Academy of Natural Sciences of Philadelphia requesting the deposit with it of the various Herbaria in the possession of this Society, was laid before the Society In connection therewith the Curators offered the following report :

The Curators recommend that they be authorized to deposit with, and take receipt from, the Academy of Natural Sciences, the botanical collection of Lewis & Clarke, the Short and Muhlenberg, the Herbarium Americanum, and such other botanical collections now in the Society's possession, on the condition named in the letter from the Curators of the Academy, that they be kept as separate collections in the Herbarium of the Academy, properly cared for and returned on demand.

The recommendation of the Curators was adopted.

The Society was then adjourned by the presiding officer.

GEOLOGY OF THE PALEOZOIC AREA OF ARKANSAS SOUTH OF THE NOVACULITE REGION.

BY GEORGE H. ASHLEY, PH.D.,
Assistant Geologist.

WITH AN INTRODUCTION BY JOHN C. BRANNER.

(*Read May 13, 1897.*)

INTRODUCTION.

In 1890–92 Dr. George H. Ashley, the author of the present paper, was entrusted with the study of that part of the Paleozoic region of southwestern Arkansas lying between the Lower Silurian Novaculite area or the Ouachita uplift on the north, and the Cretaceous area on the south. This paper gives the principal results of Dr. Ashley's work. Properly speaking it is a part of the official reports of the Geological Survey of Arkansas, but the survey was abolished by the Legislature in 1893, and no provisions were made for printing the several unpublished volumes.

Mr. Ashley was ably assisted during one field season by Prof. A. H. Purdue, now Professor of Geology at the Arkansas Industrial University, and other valuable additions were made to the work by Mr. John H. Means, who as assistant on the State Survey has worked up the geology of the Lower Coal Measures north of the Ouachita uplift. Some notes were also furnished by Dr. J. P. Smith, formerly assistant geologist on the Arkansas Survey, now Professor of Paleontology in the Leland Stanford, Jr., University. The northern border of the Cretaceous rocks was traced by Dr. O. P. Hay.

The limited time that could be spent upon the geology of the region discussed in this paper, the folded and faulted condition of the rocks, the absence of fossils and the lack of good maps have made it impossible for the author to enter into details regarding the geologic history of the area.

The divisions I have made of the rocks and the reasons for making them are accepted, not as altogether satisfactory, but simply as the best that can be offered under the circumstances. The beds I have called the base of the Coal Measures are the novaculite conglomerates exposed at Hot Springs. The reason for considering these beds as the top of the Lower Silurian or the bottom of the Coal Measures is simply that the novaculites, as considerable beds, end abruptly with this stratum, and because this bed is a conglomerate. It will be seen that there are some thin and unimportant beds of novaculite above this horizon, but they are no more to be compared with the novaculites below it than are the coal beds of the Devonian to be compared with those of the Carboniferous.

So far as I can judge from my own observations there is no marked unconformity between the Lower Silurian rocks and the Lower Coal Measures rocks, and that in spite of the fact that there are no Devonian rocks known to be such in this part of the State. The conglomerate, however, suggests the possibility of such an unconformity, and it is quite possible that the disturbed condition of the rocks has caused such a gap to be overlooked.

Mention is made at several places of a stratum of supposed igneous rocks interbedded with the sedimentary ones, and assumed by Dr. Ashley to be everywhere at the same horizon. There is some doubt in my mind as to whether this bed is everywhere the same, and also as to whether it is really igneous. There is no doubt but that the bed discovered by Dr. J. P. Smith in 5 south, 32 west, section 1, is a tuff, but at other places the rock is so changed by decomposition that it is not possible to say with certainty what the original materials were. It is also suggested by the author that these beds are to be correlated with similar rocks supposed to be volcanic tuffs and found about Cushman, Independence county, in the northern part of the State. But this north Arkansas bed turns out to be a phosphate deposit, and a chemical analysis of one of Dr. Ashley's specimens from southwest Arkansas shows it to contain an equivalent of nine per cent. of calcium phosphate.[1]

To the little proof here given of the age of these Lower Coal Measures rocks should be added that I have found Calamites in this series on the west bank of the Ouachita river in 5 south, 18 west, section 32. Attention should also be directed to the notes of Prof. C. S. Prosser on the "Lower Carboniferous Plants from the Ouachita Uplift," published in the *Novaculite Report of the Arkansas Survey* (Vol. iii, 1890, pp. 423, 424). Prof. Prosser's notes are upon fossils found north of the region described in the present

[1] See "The Phosphate Deposits of Arkansas," by John C. Branner, *Trans. Amer. Inst. Mining Engineers*, September, 1896.

paper, but the structure of the region shows that they are from rocks occupying the same geologic horizon.

The general structural features of the Ouachita uplift are so much like those of certain parts of the Appalachian structure that one naturally assumes at the outset that we have here an Appalachian type, and indeed a part of the original Appalachian folding. It cannot be stated positively that this is not the case, but it is my own opinion that the Ouachita uplift is the structural equivalent, not of the Appalachians, but of the Nashville Silurian basin and of the Cincinnati arch. To be sure the Ouachita anticline is closely pressed, while the Nashville and Cincinnati folds are very gentle. This difference is, however, a matter of structural detail only. The equivalent of the Appalachian chain and the source from which the Lower Coal Measures sediments of south Arkansas appear to have been derived (in part) was a continuation across the present Mississippi drainage of the pre-Cambrian rocks of Alabama and Georgia, etc. This region, that is the gap through which the Mississippi river now flows, has been lowered, partly by erosion, but chiefly by downward orographic movements and it is now buried beneath the Cretaceous and Tertiary sediments of south Arkansas and of north Louisiana and Texas.

This hypothesis seems to be borne out by the following facts:

I. The fossils found on the south side of the Ouachita anticline are coal plants like those from the Cumberland plateau of east Tennessee, eastern Kentucky, and West Virginia.

II. The sediments thicken and become coarser to the south as one leaves the Ouachita uplift (Ashley) just as in the upper Ohio valley they thicken and become coarser east of the Cincinnati arch.

III. In central Texas, northwest of Austin, is an Archean and Cambrian area which appears to be the southwestern end of the old Appalachian chain, and north of it are Carboniferous rocks.

IV. If the Cincinnati, Nashville and Ouachita arches are assumed to be the same general fold, this line is found to continue into Indian Territory and Oklahoma, and the arch as a whole is parallel with the Appalachian system save across the break made by the present Mississippi river depression where the same conditions would be expected.

V. The peneplain south of the Ouachita mountains and on which the Cretaceous beds were deposited slopes toward the Mississippi.

VI. The Arkansas river drainage formerly (in Carboniferous and

Permian times) flowed westward, but it has been reversed and now flows east and southeast.

VII. The igneous rocks of Arkansas and Texas are mostly along what appears to be the edge—possibly faulted—of this depression.

I have not thought it necessary to exclude or suppress in the present paper statements in conflict with other publications made by the Geological Survey of Arkansas. Reference is here made to the differences between the structural details as worked out by Dr. Ashley and those represented by Dr. Theodore B. Comstock on the map accompanying his report on gold and silver. No geologist with the two maps before him can have any doubt about which is right. It should be said, however, in defense of Dr. Comstock, that the time he could devote to the study of the region on which he had to report was very limited; and in defense of the publication of his map, that the report giving the economic results of his work (and these were correct and of great importance) was so tied to the theory of the structural lines put down on his maps that it was quite impossible to separate the two.

John C. Branner,
Formerly State Geologist of Arkansas.

I. Geologic and Geographic Position.

If in any of the Atlantic or Gulf States, one start from some point on the coast and travel inland, he will, in most cases, observe at one point a striking change both in the topographic and geologic features of the land. He has been traversing at first low-lying, then somewhat more elevated, stretches of level country, characterized, aside from its low elevation above the sea level and comparative flatness, by sluggish, meandering rivers, a luxuriant timber growth, the softness and horizontality of the rocks, consisting of unconsolidated clays, sands, gravels, etc., with an occasional hard layer, and by the freshness of the fossil remains. But as one passes the point mentioned, he comes upon a region of higher altitude, frequently or generally mountainous, with rapid rivers, more hardy but less dense timber growth, the underlying strata being highly consolidated, frequently crystalline limestones, sandstones, shales and granites, in some regions horizontal, in others highly folded and distorted.

A study of the geology on either side of the line of division shows that the region on the coast side is of comparatively recent origin, having been deposited since the close of the Carboniferous age; the harder rocks on the landward side having been deposited during the Carboniferous and preceding ages. The former, which includes the Mesozoic and Cenozoic, has been termed the Neozoic addition. The line between the two has been traced down the Atlantic coast and through northern Georgia, Alabama and Mississippi, thence following the Tennessee river into southern Illinois, where it turns, crossing the Mississippi near Cairo and running approximately southwest on the west side of the St. Louis, Iron Mountain and Southern Railway nearly to Arkadelphia, where it turns westward and follows an irregular line into the Indian Territory and Texas.

The region described in the present report lies in a belt just north of that portion of the above line running west from Arkadelphia. To define and locate it more clearly we shall first review the general geologic features of the region from this line to the Arkansas river as shown in the reports already published upon that area.[1]

The history thus revealed is briefly:

1. A long period of deposition running from early Silurian times through the Carboniferous age, and the accumulation of deposits of great thickness.

2. These deposits give way to mountain-making forces and becoming much folded are lifted into an anticline, called by Dr. Branner the "Ouachita uplift." The axis of this anticline is an approximately east and west line running from Little Rock west well into the Indian Territory.

3. A period of erosion during which the uplift is cut down until the Silurian strata are exposed along the axis. The later beds are successively exposed as one goes away from the axis of uplift.

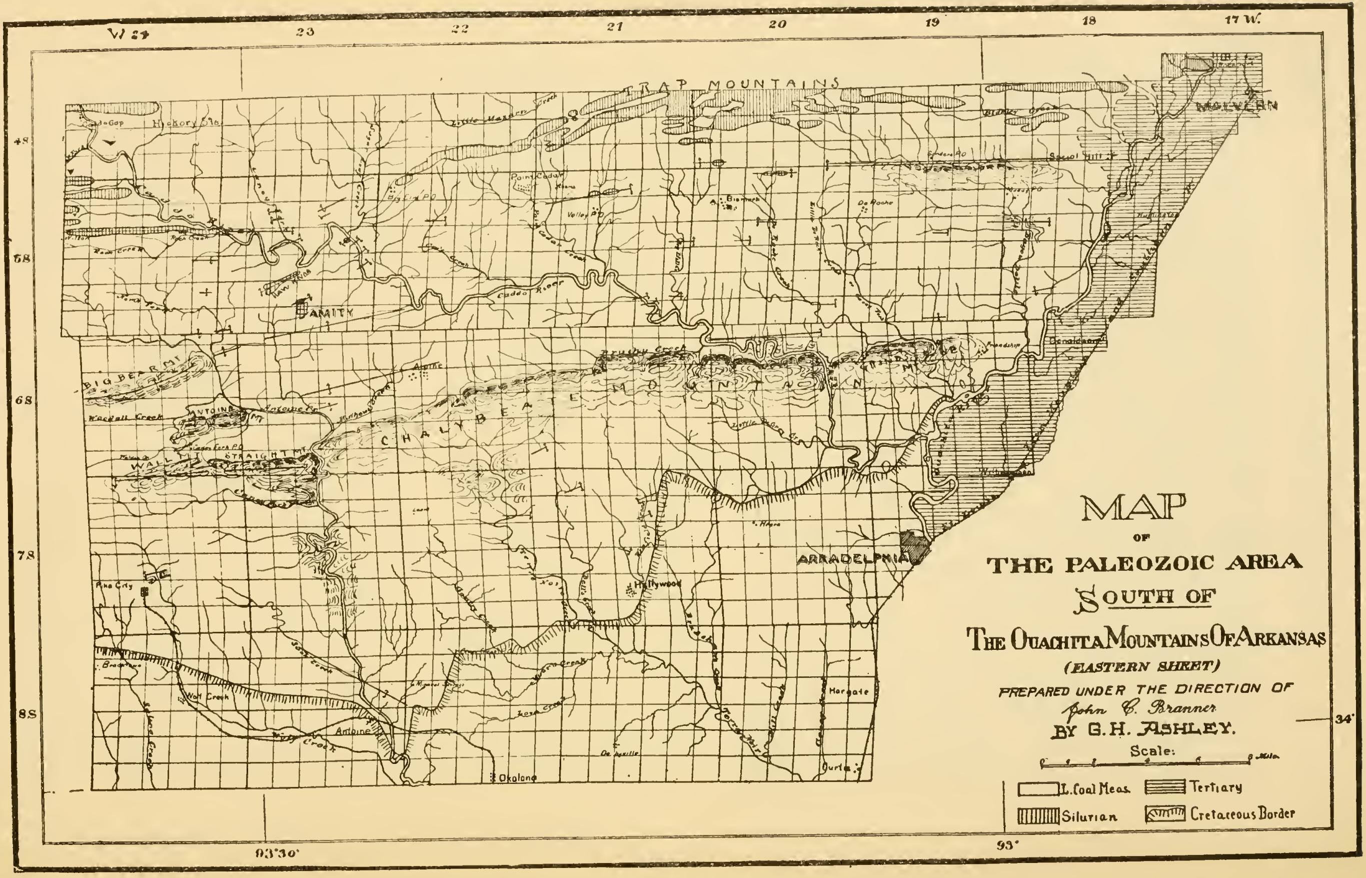
4. A period of depression and deposition upon the southern slope of the Ouachita uplift. During this period, and up to the present time, there has been a series of oscillations of level, resulting in slight nonconformity between the strata.

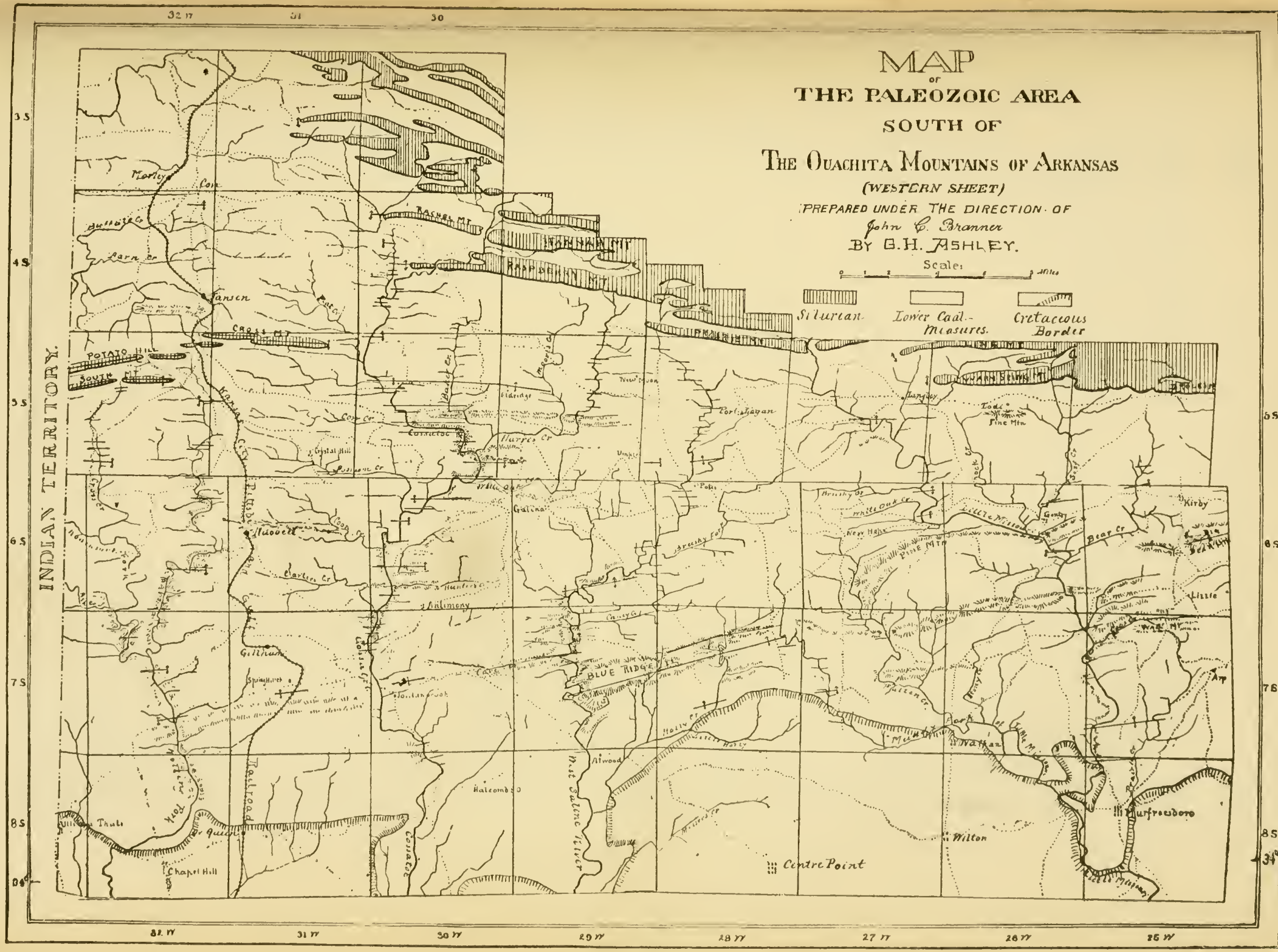
The rocks are now exposed in the following order:

1. A belt of Silurian exposures running from Little Rock a little south of west to Dallas, of which the novaculites[2] are prominent

[1] *Geol. Surv. of Ark.*, An. Rep. for 1888, Vol. iii; for 1890, Vols. i and iii.

[2] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. iii.


MAP
OF
THE PALEOZOIC AREA
SOUTH OF
THE OUACHITA MOUNTAINS OF ARKANSAS
(EASTERN SHEET)
PREPARED UNDER THE DIRECTION OF
John C. Branner
BY G. H. ASHLEY.
Scale:
L. Coal Meas.
Tertiary
Silurian
Cretaceous Border
TRAP MOUNTAINS
BIG BEAR MT.
CHALYBEATE MOUNTAIN
STRAIGHT MT.
ANTOINE
AMITY
ARKADELPHIA
MALVERN
Hollywood
Okolona
Pike City
Point Cedar
Caddo River
Little Missouri River
Antoine
Donaldson
Friendship
Harpgate
W. 24
23
22
21
20
19
18
17 W.
4 S
5 S
6 S
7 S
8 S
93°30'
93°
34°


MAP
OF
THE PALEOZOIC AREA
SOUTH OF
THE OUACHITA MOUNTAINS OF ARKANSAS
(WESTERN SHEET)
PREPARED UNDER THE DIRECTION OF
John C. Branner
BY G.H. ASHLEY.
Scale:
Silurian
Lower Coal-Measures.
Cretaceous Border
INDIAN TERRITORY.
POTATO HILL
SOUTH MT
CROSS MT
RACHEL MT
Jansen
Centre Point
Wilton
Murfreesboro
BLUE RIDGE
West Saline River
Railroad
Cossatot
Galena
Antimony
Gillham
Chapel Hill
Kirby
Pine Mtn
Little Missouri
Holcomb
Atwood
Nathan

layers. Owing to minor folds some of the higher strata are exposed in this belt.

2. To the north the higher beds are successively exposed, ending in the upper or productive Coal Measures near the Arkansas river.

3. To the south the higher strata are exposed for a short distance, but still further south they are covered by Cretaceous rocks.

4. The Cretaceous and the overlying Tertiary beds extending southward to the State line.

The strata we are to consider are those mentioned under the third head of the preceding paragraph: the beds deposited between the Silurian and the end of Carboniferous times, and exposed south of the Silurian exposures of southwestern Arkansas, and north of the Cretaceous area.

The northern limit of this area is a line starting from Social Hill in 4 S., 18 W., and touching Point Cedar, Rock Creek and Langley, then passing through the centre of township, 4 S., range 30 W., to Potter. West of Potter these beds swing around the end of the Silurian anticlinal nose and unite with the beds of the same age and character lying north of the Silurian area. On the east the boundary nearly follows the Ouachita river to the mouth of the Caddo river, thence on the south the line follows the Caddo and up Big DeGray creek, then turns south to Hollywood, then west, and follows a very irregular line, touching Clear Springs, Antoine, Royston, Nathan, Muddy Fork, Atwood, Ultima Thule, and so on into the Indian Territory.

II. Salient Features of the Region.

A General Description of the Area.—The region under consideration is a rocky, hilly country stretching along the south side of the Ouachita mountains. It varies in width from fifteen to thirty miles; the part lying in Arkansas is about ninety miles long. It is for the most part densely wooded and thinly settled. The surface is broken into a great number of valleys and ridges having an east and west trend, with a few narrow and usually rugged north and south valleys. Few, if any, of these ridges are more than three hundred feet in height.

The most common type is a ridge or table land having a steep north face, while the south side slopes away gently. A few are narrow, sharp ridges with uneven crests and steep flanks on both north and south sides. All others may be taken as variations of these two types. Sometimes the ridges can be followed for a score or two of miles; then again a ridge is prominent only where it approaches a north and south stream, and as it recedes from the stream the valleys on either side become shallower until the ridge coalesces with those next north and south of it, and is lost as a distinct ridge.

All around the southern edge of the region, the topography is of quite a different nature. It appears to be very level, though having a slight rise to the north. This level strip averages half a dozen miles in width. Its northern edge is irregular and seems to be governed by the erosion of east and west valleys into what might have been its northward extension. Novaculite gravels cover this flat region. Sandstone is the most common rock, though occasionally in the valley there are considerable beds of shale.

It is a matter of common observation among those living in the region, that the rocks almost invariably "stand on end."

While much of the region is very stony, the rocks are mostly in the form of loose blocks and boulders, but little of it being found in place and most of that is in the beds of streams.

Though the strata usually dip to the south, in some places they dip to the north. The dip is usually high, more often over than under 45°.

Just north of this Carboniferous region are the high hills or mountains of the Ouachita mountain system. The rocks in these mountains are novaculites associated with shales and sandstones.[1]

To the south these Paleozoic beds are overlaid unconformably by sands, marls and limestones of the Cretaceous.

In the eastern part of the region under discussion the main streams run east or southeast and the branches run south. The streams are not rapid and the valleys are frequently quite broad. Westward the main drainage swings around towards the south, the branches run in east-west channels, and the streams are rapid, with narrow, sometimes precipitous banks.

From an economic standpoint the most valuable product of the area is the timber. Hard and soft woods of excellent qualities abound in every part of the region.

Little of value was discovered in the line of building or other stone, nor is the region rich in ores, though small quantities of pay ore, mostly antimony, have been found in the southwestern part of the area.

Corn and cotton are the principal crops. The country as a whole is well watered and healthful.

[1] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. iii.

Much of the land is too broken for cultivation except for some hillside crop like grapes, which are said to do well here.

While most of the soil is sandy and not very rich, there is much good land along the streams, particularly in the eastern part. In the western part of the region most of the available land is on the divides.

Conclusions.—A summary of the conclusions deduced from a study of the features above touched upon can best be given as a history of geologic events in the region.

The Periods of Deposition.—The deposition of the rocks took place before the end of the Carboniferous age, and as the rocks are of both Silurian and Carboniferous ages, it must have been during these times that these sediments were laid down.

The Lower Silurian beds are the novaculites, with the accompanying shales and sandstones. The Carboniferous strata are sandstones and shales, with which occur a little grit, novaculite and some other rocks. No nonconformity has been found between the two sets of beds. The Silurian beds are believed to underlie the sandstones of the Carboniferous over all of the region, though they have been recognized at only one place.

The original thickness of the Carboniferous strata is not known, nor is it known whether the whole or only a part of the Carboniferous series was laid down over this territory. The beds remaining are thought to belong mostly to the Lower Coal Measures. The only fossils found are a few fragments of plants. No satisfactory columnar section has been obtained of the beds, but their thickness cannot be less than four or five thousand feet.

Period of Folding.—At the end of the Carboniferous age, or possibly before it, the beds of sediment in southwestern Arkansas and the adjacent portion of the Indian Territory began to yield to an apparently horizontal pressure. Gradually the great Ouachita uplift rose, and the upper beds began to fold. This continued until the upper beds were folded closely and frequently even overthrown; in fact, in this area the overthrown folds or overturns are the most common kind of fold, and testify to the intensity of the folding action.

This folding took place very slowly, so slowly that erosion may have almost kept pace with the uplifting beds. Besides the two kinds of anticlines, the normal anticline and the overturned anticline, the region is full of faults and crushed and broken structure;

so that, with the scarcity of outcrops, it is impossible to follow or trace the anticlines with accuracy, though in many cases, by means of their effect upon the topography, they may be followed with some degree of accuracy for long distances.

These folds have a nearly east and west trend, and are crossed in traversing the region in a north and south line.

On one such line there are as many as thirty-nine anticlines in a distance of twenty-four miles. Many of these anticlines cannot be found at more than one place, others may be traced for a score or two of miles. Normal anticlines sometimes merge into overturns.

A Period of Erosion and Sinking.—As already suggested, the erosion during the period of active folding may have been considerable; so that it is probable that at no time did the elevations over the area at all approach the altitude that a restoration of the eroded strata would make. At last the time came when erosion exceeded elevation and probably sinking took place over the whole region. This resulted in the formation of a base level of erosion.[1] That is, the land level in its lowest part was so near sea level that subaërial erosion was entirely expended in wearing down the elevations, and as the sinking proceeded and the oceanic waters advanced, wave action completed the leveling process. Evidences of this old sea bottom are abundant; only the narrow remnant of flat country fringing the south edge of the area need be mentioned here.

The exact extent of this inundation is unknown, but there are reasons for believing that it extended north of the region under consideration.[2] During this inundation the Cretaceous beds, of which a remnant is still found lying unconformably on the southern edge of the region, were laid down.

All details of the record of events during Cretaceous times are lost in the region to be studied, the evidence only permitting us to say, that some time previous to the Cretaceous the area was reduced to a base level, after which the Cretaceous beds were laid down. The region may have subsequently been subjected to several periods of erosion and deposition.

Following some or all of these periods of deposition came elevation, with the centre of elevation in the neighborhood of the Rich

[1] Dutton, *Tertiary History of the Grand Cañon District*, p. 76.

[2] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. iii, p. 220.

mountain. This, then, became the centre of drainage for southwestern Arkansas and the adjacent part of the Indian Territory, the streams flowing away in every direction over the newly exposed beds of Cretaceous material. A glance at a map of Arkansas and Indian Territory will show that the streams thus started have persisted to the present.

After these streams had cut through the overlying Cretaceous they struck the hard layers of Carboniferous sandstone, and slowly cut their channels down through the harder layers standing across their path. In the course of time the Cretaceous beds were completely removed from the region north of the existing Cretaceous border. The period ends with the deposit of Tertiary beds over the eastern end.[1]

A Recent Subsidence.—There has been a recent subsidence of the region which probably did not submerge the novaculite mountains to the north, but brought them in range of wave action. The hard novaculites tend to disintegrate into blocks rather than fine material, and as the waters receded, these blocks of novaculite with others of sandstone were rounded by wave action, broken up and the whole scattered as a great gravel bed, in places at least one hundred and fifty feet deep and probably much more, over the area and far to the south. This subsidence is thought to have taken place in post-Tertiary time. The greater portion of the novaculite and sandstone drift laid down in the preceding period has been removed recently, leaving only a narrow strip undisturbed on the southern edge, and in patches all over the region, where the larger boulders have resisted erosion.

III. Original Stratigraphy.

In this chapter will be considered the character, thickness and manner of deposition of the Paleozoic beds. It will be practically a consideration of the first period in the history of the region, as outlined in the preceding chapter.

Petrology.

Rocks of the Novaculite Series.[2]—The divisions of the rocks of the novaculite series made by Mr. Griswold will be followed. These rocks he divides as follows:

[1] *Geol. Surv. of Ark.*, An. Rep. for 1892, Vol. ii.

[2] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. iii, p. 122.

I. Ouachita stones: those novaculites which "originally contained a large percentage of lime."

II. True novaculites: these are the characteristic rocks of the mountains of the Ouachita system. They are believed by Mr. Griswold to be mechanical sediments. They are nearly pure silica, though "originally containing a small percentage of lime." In color they are white, black, red, yellow, gray and mottled.

III. Silicious shales, containing "little lime, but with more abundant clay."

IV. Sandstones and quartzites.

V. Chert.

The finding of a large number of species of graptolites in the silicious shales has shown that the novaculites are of Lower Silurian age and probably belong to the lower part of the Trenton.

Petrology of the Carboniferous Area.

Sandstones.—Probably nine-tenths of the Carboniferous beds are sandstones. Mr. Griswold has described a microscopic slide of sandstone from Grindstone Ridge in 6 S., 20 W., which gives the characteristics of a typical sandstone of the region.[1]

"This stone is coarse grained, light gray in color." It contains only a small amount of "iron and earthy material."

"There are rounded as well as angular quartz grains, and a few grains of decomposed feldspar are present. The quartz grains appear to have been eroded against and even into one another; many of them exhibit lines or striations, which probably result from pressure. Since these lines are not continuous from one pebble to another, and have apparently no relation to each other, they must have been produced in some manner on the original grain and in the original rock. Some of the quartz grains show secondary silica added to the original grain to form crystal faces as described by Irving in his article on quartzites.[2] One quartz fragment is filled with very fine needles which may be rutile."

The specimen is a trifle finer grained than the average sandstone. The sandstones naturally grade into each other, but certain artificial divisions may be made for convenience. These rocks have not been, as a rule, identified with any definite position in the strata.

[1] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. iii, p. 141.

[2] *Fifth Annual Report of the United States Geological Survey*, pp. 221–223.

(*a*) The sandstone most commonly met with is a soft, olive green sandstone, upon exposure decomposing rapidly into sand. Except when freshly exposed this rock is seldom seen in its massive state; but its soft edges are constantly found in the roads and over the more level territory. Probably this sandstone differs from the next only in lacking iron.

(*b*) The bulk of exposures of a massive character are of a ferruginous sandstone, usually a dark red or brown. In this, exposure to the air oxidizes the iron, which forms a cement and makes the exterior much more impervious. Frequently the brown color penetrates only a short distance, and the interior is a steel gray or light green in color.

(*c*) In a few localities a very white sandstone was found. Surface exposures are usually quite soft. Where fresh, as was found in digging a well on the farm of Mr. Tom Hodges in 6 S., 19 W., section 4, it is exceedingly tough, making digging very slow and laborious. A few months' exposure of the rock is sufficient to render it very friable and mealy. In places it shows slight traces of pyrite.

(*d*) Of frequent occurrence are varieties of finely laminated sandstones verging into shaly sandstones or arenaceous shales. These are usually dark colored or black, and, where the layers are not too thin, are said to make good stones for chimneys and fireplaces. They often occur in layers not more than a quarter of an inch thick, and are frequently found interbedded with shale. There are many intermediate forms, and varieties differing both in hardness and color, but they are not worthy of special mention.

Shales.—The presence of the shales is usually indicated only by the topography or by their being struck in digging wells. Single beds are seldom over fifty feet thick, though in a few places it has a thickness of from one hundred to three hundred feet, and in one place on the Cossatot, in 6 S., 30 W., section 19, it appears to have a thickness of six hundred feet. In one place a thickness of twenty feet was seen to thin out within two hundred to three hundred yards.

It varies in lithographic characters very like the shale of other regions; sometimes it breaks up upon exposure into long, slender, needle-like fragments; sometimes it breaks up into thin laminæ or flakes; at other times it is traversed by joints that cause it to break into angular blocks, and these all weather rapidly into clay. In color they are black, lead colored, cream colored, and reddish.

Conglomerate.—First found in the Chalybeate mountain where cut by the Caddo, and later in a large number of places over the region, occurs a coarse grit or fine conglomerate. In places this forms a distinct bed eighteen inches or a few feet thick, but oftener it mingles in indistinct layers with the sandstones in a bed from fifty to one hundred feet in thickness, and varies all the way from a conglomerate to the fine-grained sandstone with which it is associated. It consists of small, rounded grains of milky quartz, none of which are more than a quarter of an inch in diameter, cemented by fine sand and iron.

Novaculite.—Reference is here made to a layer of novaculite from two to six inches thick which is found well scattered over the region. Considering the thinness of the layer, its persistence is remarkable, as it was found from range 22 W. to the territory line, and from the novaculite mountains to township 7 S. Unfortunately its exact position in the series could not be determined, but it seems certain that it is above the Silurian novaculite series, yet not separated from that series by more than a few hundred feet. In only one case was it found in a creek section ; it usually appears only where the layer is crossed by a road or field. At such places it can be followed by the fragments of novaculite which lie on the surface. In 5 S., 22 and 23 W., it was traced for about six miles, and at other places it wsa traced for shorter distances. It appears to be invariably associated with beds of silicious shales, the whole aggregating a thickness of about fifteen feet. In the centre occurs the characteristic novaculite from two to six inches thick. On either side of the novaculite layer is an exceedingly fine-grained silicious shale with hackly fracture, differing from novaculite in appearance only in that the grain can be made out. From this the transition may be traced through less and less silicious shales, until, at a distance of seven or eight feet on either side, it has entirely given up its silicious character and appears to be a soft, argillaceous shale, crumbling easily in the fingers, its only resemblance now to the neighboring novaculite being its color, as it still retains the peculiar drab and pink which run through the whole series.

Igneous Rock.—There appear in many places from Amity westward outcrops of rocks containing white specks a sixteenth of an inch in diameter and smaller. Other unknown ingredients appear in thin sections, but in hand specimens the white specks are a characteristic by which it can be recognized. The rock matrix in which this white material occurs does not appear to be constant. In places it is a hard rock ringing under the hammer, with the white specks sparsely scattered through it; in other places it is a quartzite; in some places the white and yellow specks occur in a matrix of shining black rock; in others in a shaly breccia; but the matrix is generally a light green earthy material.

The proportion of white material varies from a very small per cent. to rocks in which there is little else. In many of the harder beds the soft white material weathers out, giving the rock a very cellular appearance. A typical locality is on the Amity-Hot Springs road a mile north of Amity. It here forms a bed thirty-three feet thick. It appears to be regularly bedded at every exposure found. It is well exposed in front of the Bushy Mill in 4 S., 30 W., section 7, and on the Line road, in 5 S., 32 W., section 1. It is apparently but a short distance above the novaculite series. Williams and Penrose, of the Arkansas Survey,[1] report a similar deposit in north Arkansas, which there occurs on the dividing line between the Silurian and Lower Carboniferous strata. The examinations which they have made microscopically and otherwise have led to the suggestion that this is an ash bed indicating volcanic activity somewhere at the end of the Silurian. The great variation in the matrix rocks would seem to agree with such a theory.[2]

Novaculite Breccia.—At the same locality a mile north of Amity on the Amity-Hot Springs road are found many fragments of a novaculite breccia. This is probably the same as the novaculite conglomerate referred to by Mr. Griswold, but in this case it is invariably a breccia, the fragments which here measure from an inch or two in diameter down, presenting no evidence of previous erosion.

The matrix of this breccia is usually a light green sandstone, though in a few instances it is reddish or brown. The fragments which in some cases make up the bulk of the rock, in others only scattered through the sandstone, are of novaculite and vary in color from white to red or black.

Changes in the Rocks. Sand and Clay.—The most universal change is the disintegration of the rocks into sand and clay. Pos-

[1] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. ii, p. 375, and Vol. i, p. 128.

[2] Chemical analyses of the north Arkansas beds here referred to show that they are phosphate rocks. An example of the rock collected by Dr. Ashley was found to contain only nine per cent. of calcium phosphate.—*J. C. Branner.*

sibly related to the sandstone is a white, friable, decomposed sandstone found at a few places. A typical locality is in fields about a mile north of Amity near the Caddo Gap road. It crumbles between the fingers into a white, dust-like powder; when dry it is almost as white as chalk. This soft, decomposed condition extends to such a depth that gullies once started in it, cut deep, cañon-like ditches resembling those so common in the soft Cretaceoul marls of the region to the south.

In this sand are great numbers of concretionary ironstones, from the size of the fist up to three or four feet in diameter. These are strewn over the surface, or protrude from banks, or occasionally may be observed capping a short column of the surrounding soft material. They are usually dark brown and consist of several layers averaging half an inch thick in which the proportion of iron is quite large, surrounding a kernel of exceedingly tough gray sandstone.

Beside the ironstones, this sand is found in some places intersected by numerous joint-planes filled with thin films of iron. Quartz veins and crystals are especially abundant in localities of this nature. Through the sand are frequently little nodules of silicious shale invariably incrusted with a soft, yellow layer. These iron incrustations are formed by waters dissolving out the iron and other impurities which are again deposited in the numerous joint planes; the quartz is deposited at the same time. Quartz filling the crevices in the sandstone is abundant over most of the area. While in some places this forms only a film just thick enough to give a sparkling appearance to the rock when broken open, in others it occurs as solid veins a foot or more in thickness, which may withstand weathering better than the enclosing rocks and may appear as a low wall across the country. The smaller veins, as a rule, intersect the bedding planes at right angles or at a high angle; but many of the larger ones run parallel to the strike. There is such a case in 7 S., 32 W., sections 8 and 9, on Robinson's Fork of the Rolling Fork of Little river, where a protruding vein of quartz can be traced a mile or more in the line of strike.

Masses of interlocking crystals occur frequently, and occasionally well-formed single crystals are found. In many places in the western part of the region, the ground is completely covered with fragments of quartz, as on the "line road" in 5 S., 32 W., section 25, where the road is paved with quartz for nearly half a mile.

Superposition of the Beds.

Mr. Griswold divides the Silurian strata into two series; the novaculite series, and the beds below the novaculites. The beds below the novaculites he estimates to be 1300 feet in thickness, as far down as exposed. They consist of gray, black and yellow shales at the bottom, cherty blue limestones next above, then massive quartzose sandstones, limestones, and shales.

From several columnar sections the novaculite series appears to vary greatly in different localities. He gives, however, a generalized section, in which the order from the bottom upward is: Silicious shales, 200 feet; shale, 300 feet; novaculite, 250 feet; shale, 100 feet; novaculite, 100 feet; novaculite with silicious shale at bottom, 250 feet; novaculite breccia or conglomerate, a thin layer.

The variation in these layers may be judged by an examination of Mr. Griswold's sections.[1] Thus, as an example, the upper layer of novaculite in the Boss Allen Creek section is 500 feet thick, while in the South Fork of the Caddo section it is only 60 feet thick.

Stratification of the Carboniferous Beds.—No satisfactory columnar sections of the Carboniferous beds were obtained.

Outside of the immediate channels or banks of streams, rock exposures are rare, and when found are seldom extensive enough to give more than the dip, and the rock exposures in the stream are not usually more than a few yards long. Now and then a continuous exposure is found for several hundred feet, and in a few cases longer exposures are found; but usually between the long exposures there are so many stretches concealed, in which may be folds, or faults, or other unknown factors, that one cannot be sure of the structure. Had the beds been such as to permit identification and correlation, doubtless satisfactory sections could have been made. On Plate I are given the best general sections obtained.

Plate I, Section I.—This section was obtained on the Rolling Fork of the Little river. In 8 S., 32 W., the lower part of section 11, is a perpendicular bluff on the east bank of the Rolling Fork known as the "Buzzards' Roost." The dip at this point is about 12°, S. 18° E. Continuing up stream, sandstone is met with in bluffs and in the stream bottom almost continuously, dipping from

[1] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. iii, Pl. iii.

10° to 15°, until shales are met with in the flats at the Bellah mine. Only one important break occurs, where the valley of Rabbit creek comes in. At this point may be a heavy bed of shale, and shale may exist at other points along the section, but was not seen.

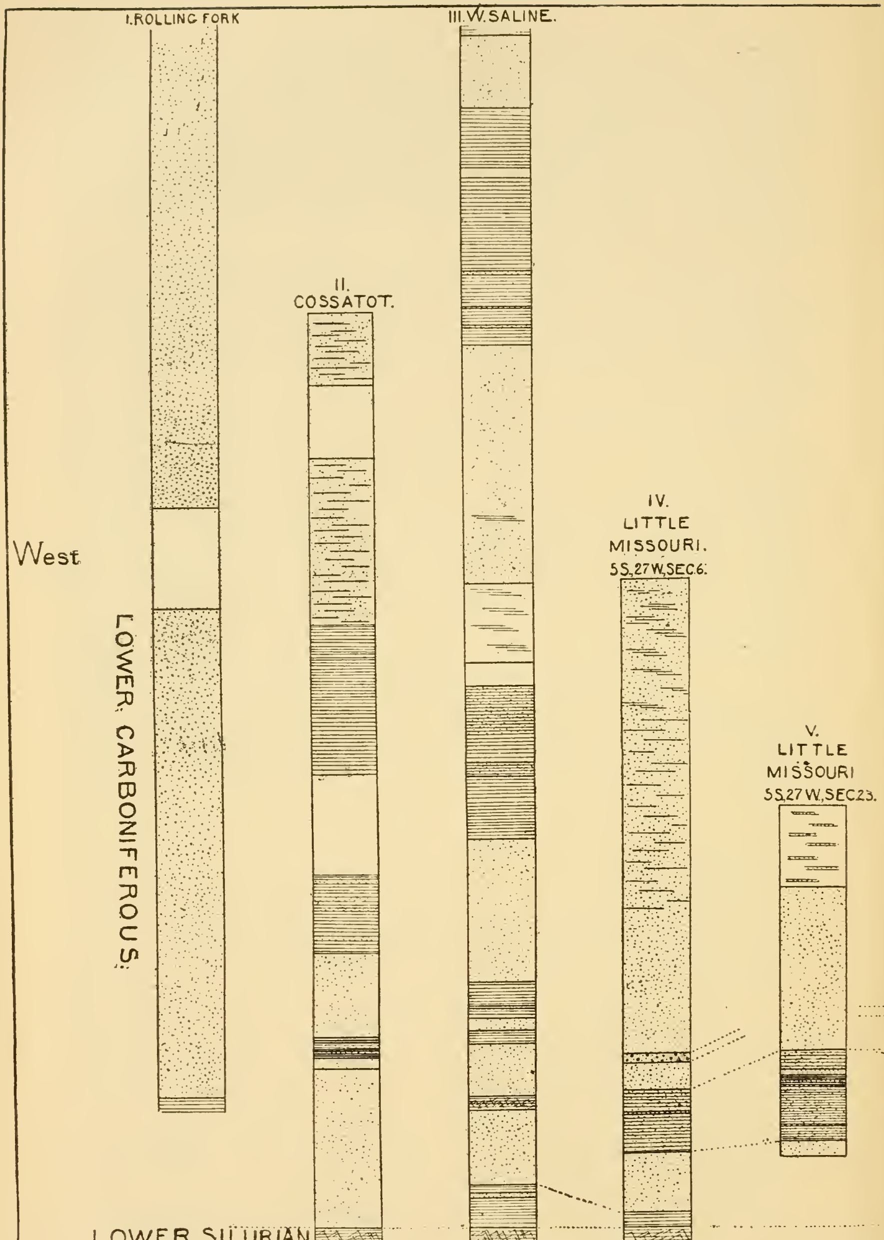
From 1500 to 2000 feet of sandstone are omitted from the top of this section. The existence of faults is quite possible, but no evidence of any was found.

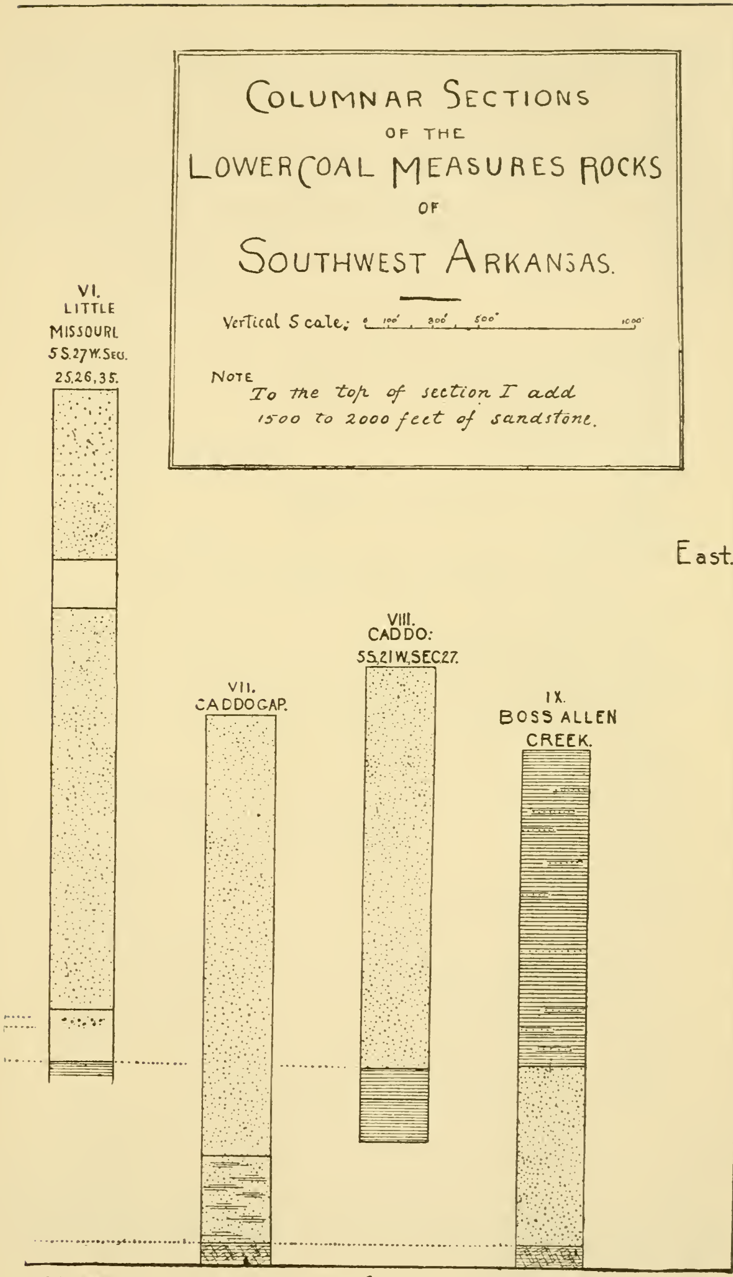
The position in which this section is placed relatively to the others is based upon the occurrence, in the strike of these shales and six miles to the east, of the thin beds of novaculites and shales which are known to be not far above the principal bed of novaculite.

Section II.—Section ii shows the order of rocks on Cossatot river at the gap near Pontiac post-office. The ridge crossing the Cossatot just north of Pontiac has black novaculite exposed at the centre of an anticline. The section starts from the exposure of novaculite in the gap, and runs south to where the river turns northwest half a mile below. The sandstone overlying the novaculite is poorly exposed on the south side of the anticline, but shows on the north side, and also on the south side of the ridge, east of the river. A careful section was made at this place, but as the shales and sandstones at many points in it are crushed together and broken, suggesting faults, the section is not altogether trustworthy. Omitting minor details the section is as follows:

	FEET.
Sandstone	150
Concealed	150
Heavily bedded sandstone with thin beds of shale	375
Shale with occasional beds of sandstone	325
Concealed	225
Shale and sandstone much crushed	175
Sandstone in thin beds	175
Shale and sandstone layers	50
Sandstone	25
Sandstone and quartzite	350±
Black novaculite	base
Total	2000

Plate I.


I. ROLLING FORK
III. W. SALINE.
II. COSSATOT.
West
LOWER CARBONIFEROUS.
IV. LITTLE MISSOURI. 5 S, 27 W, SEC. 6.
V. LITTLE MISSOURI 5 S, 27 W, SEC. 23.
LOWER SILURIAN


COLUMNAR SECTIONS
OF THE
LOWER COAL MEASURES ROCKS
OF
SOUTHWEST ARKANSAS.
Vertical Scale:
NOTE
To the top of section I add
1500 to 2000 feet of sandstone.
VI.
LITTLE
MISSOURI.
5 S. 27 W. Sec.
25, 26, 35.
VII.
CADDO GAP.
VIII.
CADDO:
5 S. 21 W. SEC. 27.
IX.
BOSS ALLEN
CREEK.
East.

This section is broken at its southern end by a fault of unknown throw.

Section III.—Section iii was recorded by Prof. A. H. Purdue on the West Saline river, beginning at the gap near Moore's mill, 4 S., 28 W., section 31, and running south about a mile. This section, like the preceding, is not altogether trustworthy, for the strata are frequently nearly perpendicular and may be overthrown or faulted. The section, omitting minor details, is as follows:

	FEET.
Sandstone	10
Shale (probably)	75
Sandstone	165
Shale (probably)	165
Concealed	20
Shale with a few layers of sandstone	375
Sandstone	530
Thin bedded sandstones and shales (poor exposure)	175
Concealed	50
Thin bedded shaly sandstone	100
Green shale	50
Thin bedded shaly sandstone	30
Shale	135
Sandstone	320
Green shale	70
Sandstone	10
Green shale	25
Quartzose sandstone	35
Green shale	30
Sandstone with some shale	115
Novaculite and shale	45
Quartzose sandstone	115
Shale with few quartzitic sandstone layers	100
Thin beds of black novaculite and shale	400
Total	3195

Section IV.—Section iv was observed on Little Missouri river beginning at the gap where the river cuts through Prairie mountain in 5 S., 27 W., section 6.

The anticline at this gap shows nicely; the section as given on Pl. i begins with the top of the black novaculite and shale. The section is as follows:

	FEET.
Sandstone with some shale (poor exposure)	300
Sandstone with thin layers of shale............	400
Sandstone..................................	365
Grit or conglomerate	25
Sandstone..................................	60
Shaly sandstone in thin layers................	140
Sandstone, soft yellow where weathered	130
Shale......................................	30
Black novaculite and shale....................	400
White novaculite............................	400
Shale and sandstone	base
Total....................................	2450

The thickness of the Carboniferous in this section is about 1600 feet.

Section V.—Section v is on Little Missouri river, in 5 S., 27 W., section 23, on the north and south stretch in the middle of the section. The section obtained was:

	FEET.
Sandstone, all that showed (poor exposure).....	185
Sandstone..................................	370
Shaly sandstone thin bedded.	40
Sandstone..................................	10
Shale......................................	15
Sandstone..................................	5
Shaly sandstone thin bedded, with some hard sandstone.	130
Sandstone..................................	30
Total....................................	785

This section is well exposed along the river bank, and is accurate as far as it goes. The dip at the north end is high, but quickly becomes low.

Section VI.—Section vi is on Little Missouri river, beginning at Pine mountain, in 5 S., 27 W., section 26, and running south to where the river turns east and northeast. The dip is low, from 10° to 20°. At the north foot of Pine mountain a bed of shale is exposed, then for a short distance it is concealed beneath broken sandstone blocks. Near the top of the mountain on the north side in this area of no outcrops were found many pieces of grit or conglomerate, indicating its presence there in place. Massive layers of sandstone, twenty to forty feet thick, form the top and south slope, dipping 20° south. For most of the rest of the distance the sandstone is exposed almost continuously in low, perpendicular cliffs, the dip being very low. This is thought to be a single outcrop to the centre of section 31 in the next township east. This cross-section and the preceding are separated only by a short stretch in which there are no exposures. The dip is the same, and it is possible that the two are part of one section; many things, however, point to its being a repetition of the preceding section, and the topography also is suggestive of a fault between the two.

The section gives:

	FEET.
Sandstone	400
Concealed	100
Sandstone	900
Concealed	115
Shale	30
Total	1545

Section VII.—Section vii, at Caddo Gap, is quoted from Mr. Griswold.[1]

It is as follows:

	FEET.
Sandstone	980
Sandstone with some shale	200
Silurian novaculites, etc	base
Thickness of the Carboniferous beds	1180

Section VIII.—Section viii is on Caddo river, in 5 S., 21 W., section 27. A long stretch of low dip (from 5° to 10°) with continuous outcrops gives this section:

[1] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. iii, Pl. iii.

	FEET.
Sandstone	900
Shale	75
Black shale with fossils	100
Total	1175

There is evidence of much shale below the bottom of this section.

Section IX.—Section ix is on Boss Allen creek, in 3 S., 18 W.; it was obtained by Mr. Griswold.[1]

	FEET.
Shale with some sandstone	700
Sandstone	400
Novaculites, etc. (Silurian)	
Thickness of the Carboniferous	1100

Besides these sections, mention might be made of a continuous outcrop of perpendicular sandstone with some thin layers of shale, which forms the east bank of the Little Missouri in 6 S., 26 W., section 25. In this outcrop the beds exposed have apparently a thickness of 1500 feet.

On the Cossatot, in 6 S., 30 W., section 19, is a continuous exposure of arenaceous shale or shaly sandstone giving a thickness of 600 feet, which is much greater than the exposure of the same rock elsewhere.

On the Cossatot, in 5 S., 30 W., section 17, is a fine exposure of sandstone which at this point crosses the river in high massive ledges from ten to twenty feet thick and dipping north 30°. The river cuts through these ledges forming a series of cascades known as the Falls of the Cossatot. The thickness is about 800 feet.

Stratigraphic Position of the Beds.

(*a*) *The Novaculite Breccia.*—The novaculite breccia was only met with in quantity a mile north of Amity (see p. 232). It appears there following the strike of the rocks. Mr. Griswold reports[2] a novaculite conglomerate or breccia occurring just at the top of the novaculite series. This is thought by Dr. Branner to be the top of the lower Silurian strata.

[1] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. iii, Pl. iii.

[2] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. ii, p. 300.

(*b*) *Igneous Rock.*—This is well shown at the same locality as the breccia, and there appears to occupy about the same horizon. It was found at about a score of places west of the Cossatot, these being always, where the structure was known, just at the axes of anticlines; and, as in many places among the novaculite mountains, it is found very close to the novaculite, it may be safely assumed that it is but a short distance above the novaculite, and may well be taken, as has been suggested, as the dividing line between the Silurian and the Carboniferous.[1]

(*c*) *The Thin Bed of Novaculite and Associated Shales.*—Notwithstanding the large number of places at which this bed was met with, it only appears in one of the columnar sections. In the Saline section it appears not much more than one hundred and fifty feet above the top of the black novaculite and shales. It is usually exposed near anticlines; in many cases, exposures are found on each side of the anticline. This would place it low in the series, but the distance between the exposures, frequently a quarter of a mile, and the distance of exposures from the thick-bedded novaculite, where exposed in the fold over a novaculite ridge, suggest that generally this thin layer of novaculite is several hundred feet above the black novaculite. Considering the thickness of the bed, from three to ten inches, it is remarkably persistent; the most southern exposures in township 7 S. appearing practically identical in thickness and character with the exposures close to the novaculite ridges.

In the Saline section it is in a thick bed of sandstone. In a fine exposure on the Caddo in 5 S., 23 W., section 21, northwest corner, there are thick beds of shale above and below it, and it shows this difference in many exposures.

Whether or not it is above or below the lowest of the beds which, by their fossils, are known to be Carboniferous, is not known. If it is below and belongs to the Silurian novaculites, we must acknowledge the existence of belts of Silurian strata all through the area. If it is above, as seems possible, we have the remarkable case of unusual conditions which dominate in one age returning after a long interval in a much later age, not in a single locality, but widespread though of short duration.

(*d*) *The Grit or Fine Conglomerate.*—In Pl. i, Sec. iv, on the

[1] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. i, p. 128, and Vol. ii, p. 375. For doubt regarding the igneous nature of some of these beds see footnote on p. 232.

Little Missouri, the grit appears about four hundred feet above the black novaculite. In the Cossatot section it appears east of the river just below the shales and not more than six hundred feet above the black novaculite. This, together with the fact that it is usually found elsewhere close to the anticlines, indicate that it is not far above the novaculite, probably within a few hundred feet. Its relation to surrounding beds varies greatly: in places it is just below thick beds of shale, in other places it is just below thick beds of sandstone; hardly any two exposures agreeing, so that while lithologically it is very similar wherever found, it is quite possible that the different exposures are only local in extent and occur in different horizons. In several places, however, the grit has been traced in more or less continuous exposures for several miles.

A General Section.—Could we construct a general section it would be somewhat as follows:

5. Sandstones forming top of exposed beds and having a thickness at one place of four thousand feet or more.

4. A variable set of beds of shale and sandstone measuring at least several hundred feet in which occur,

(*a*) A bed of beds or grit.

(*b*) A thin bed of novaculite and silicious shales.

3. A bed probably of igneous origin, thirty-three feet.

2. A thin bed of novaculite breccia.

1. Silurian novaculites, shales and sandstones.

IV. Fossils and Age of the Strata.

Caddo River Locality.—The first and most promising locality at which plant remains were found is in 5 S., 21 W., on the tongue of land just east of the mouth of Point Cedar creek. There is here a good exposure of black, carbonaceous shale having a peculiar hackley fracture. This contains a great many minute fragments of plants. Only a few are large enough to show any characters; of these the most common are long stems showing no branches, but ribbed longitudinally. These stems average a quarter of an inch in width by several inches in length. They are the most common fossils found in the area. They occur at several places, but at none of these places were any obtained which would permit a closer identification than that they were the stems of some plant. There was also found at this point a fragment of a larger stem showing leaf scars. The original material of the specimen has been carbonized. The specimen was not identified. Small round stems are also found at this place, but though showing some structure under the microscope, they were not identified. This and the next were the only localities found which promise fossils of value on further exploration.

Bluff Mountain Locality.—Sparsely scattered through the shale and sandstones forming the northern part of the bluff on the west side of Antoine creek at Bluff mountain in 7 S., 23 W., section 34, were found many fragments of stems similar to those mentioned above.

Suck Creek Locality.—The same kind of stems were also found in a loose block, well up on the north bank of Suck creek in 7 S., 23 W., section 30, at the bend where the creek changes from an east to a south course.

Chalybeate Mountain Locality.—Where the Caddo Gap road crosses the Chalybeate mountain in 7 S., 24 W., section 1, the rocks exposed in working the road near the top show traces of plant life, but nothing was found that could be identified.

Little Missouri Locality near Murfreesboro.—On the Little Missouri river in 8 S., 25 W., section 6, a few of the stems common to this region were found in an argillaceous sandstone.

Little Missouri Locality near Pine Mountain.—Plant fragments like those mentioned above were also found on the Little Missouri in 5 S., 27 W., section 23, in the shales in the bend of the river half a mile north of where Pine mountain strikes the river.

Little Missouri Locality near Gap.—A short distance south of the Gap in 5 S., 27 W., section 5, at the south end of the layers of shaly sandstone, the shale or sandstone is full of carbonaceous streaks and patches, which prove to be remains of stems of plants very poorly preserved. The impression of a stem with a thorn was found at this point. The stratigraphic position of this locality is shown on Pl. i, Sec. iv, the specimens are from the top of the arenaceous shale just below the grit shown, and only about 300 feet above the black novaculite and shale.

Star-of-the-West Locality.—On the south bank of the creek (just south of Star-of-the-West), at the foot of the hill, was found a section of a stem an inch and a half in diameter which is probably a Calamites. This was found loose on the hillside and probably came from the shales which form the bank at this point.

Panther Bluff Locality.—At Panther Bluff on the Saline river in 6 S., 29 W., section 33, shales are interbedded with sandstones, and in these shales a fragment showing the peculiar ribbing and jointing of the Calamites was found. This was the only specimen found of which the genus could be determined with certainty.

Saline River Locality near Antimony Cave.—Prof. Purdue found fragments of plants on the Saline at the bend just above Arsenic Cave in 7 S., 29 W., section 21. They are too poorly preserved for identification.

Animal Remains.

Some fragments of crinoid stems and a few bryozoans, were found in a loose quartzite boulder near the crossing of Antoine creek by the Old Military road (8 S., 23 W., section 24). The only other evidences of animal life found were what are thought to be tracks of worms or crustaceans. These were found at two localities in 5 S., 23 W., section 31, on the Amity-Kirby road, a quarter of a mile west of the crossing of the North Fork of Antoine creek, and also in section 14, on a knoll southeast of Sugar Loaf mountain.

Geologic Age of the Rocks.

The age of the Silurian strata has been determined by means of the numerous graptolites found in the shales associated with the novaculite. The shales containing these graptolites have been correlated with the Norman's Kill beds of New York, and are referred to the lower portion of the Trenton series.[1] These fossils fix the age of the Silurian beds.

Of the fossils found in the overlying Lower Coal Measures rocks only three have any diagnostic value: the two specimens of Calamites and the stem found on the Caddo, which shows the leaf scars. These plant remains are probably of Carboniferous age. The stems and other fragments often found are of no value, as they might occur anywhere from the Cambrian up, but from their association on the Caddo with the stems believed to be Carboniferous, it has been assumed that they belong to the Carboniferous, and that all beds in this particular region in which they occur are Carboniferous.

Upon the above grounds it has been thought safe to refer the strata above the novaculites to the Carboniferous age. The grits which cap the mountains along the northern face of the Boston

[1] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. iii, p. 418, *et seq.*

mountains gradually dip south and disappear under the heavy beds of the Coal Measures which fill the syncline of the Arkansas river basin. If these beds persist to the south they should appear again on the north side of the Ouachita uplift, and should disappear with a south dip on the south side of the uplift. The State Geologist is of the opinion that the grits described in this area represent the southern extension of the Millstone Grit of north Arkansas. The two are identical in appearance, except that the rocks of the southern area are never as coarse grained as some of that to the north.

The Millstone Grits of north Arkansas are at the bottom of the Coal Measures; so that if the grits south of the Ouachita uplift be correlated with those of north Arkansas we must consider that we have strata referable to both the Coal Measures and Lower Carboniferous or Mississippian series.

Without regard to time, it seems highly probable that the strata south of the Ouachita uplift were originally continuous with those just north of it. No direct proof of this has been found, nor has anything been found that conflicts with this theory.

Previous Correlations.

Thomas Nuttall, who was in this part of Arkansas in 1819, published many observations on the geology, but he found no fossils in these lower sandstones and made no attempt to correlate them.[1]

In 1834, G. W. Featherstonhaugh, U. S. Geologist, made an examination of the elevated country between the Missouri and Red rivers.[2]

He passed along the eastern edge of our region and down the Ouachita river. The ferruginous sandstones he referred to the Old Red Sandstone (Devonian) of England, which he thought to rest upon the grauwacke, the grauwacke being the shales and shaly sandstones at the bottom of the series.

He failed to recognize the intimate relation between the shale and sandstone or the folded condition of the strata. He was originally

[1] "Observations on the Geological Structure of the Valley of the Mississippi," by Thomas Nuttall, *Jour. Acad. Nat. Sci. of Philadelphia*, Vol. ii, Pt. i. Phila., 1821, pp. 48–52.

[2] *Geological Report on an Examination made in 1834 of the Elevated Country between the Missouri and Red Rivers*, by G. W. Featherstonhaugh, Washington, 1835, p. 71.

led to this classification, as Marcou [1] and others have been, by finding at Little Rock the highly contorted shales at the "Little Rock" and a few miles above, at "Big Rock," the almost horizontal sandstone strata. In 1842, Dr. W. Byrd Powell [2] questioned Featherstonhaugh's correlation with the grauwacke, but he accepted it as the best that could be given, but included the sandstones in the same classification. Dr. Englemann saw something of the region between Little Rock and Hot Springs, but he found no fossils, and the only suggestion as to correlation was that the sandstone at Little Rock was "most probably analogous to that of Lake Superior."[3]

Owen refers this region to the Millstone Grit,[4] including in the same formation the novaculites, which we now know to be Silurian.

He concludes that these beds have an immense thickness from observing sections many miles long, where the beds appear to dip steadily in one direction. This has since been shown to be due to a number of consecutive overturns.

Subsequent Observers.—Since the beginning of the present survey, several of its members have crossed this region. No fossils were found, and so, though Mr. Branner provisionally referred these beds to the Lower Carboniferous,[5] he thought it better to speak of them simply as Paleozoic.

Extent of Beds.

It can be assumed with some degree of certainty that the strata exposed over the area under discussion are continuous. This refers only to the beds as a whole, not to individual layers.

The extent to the south and east can only be conjectured, but as no thinning out could be detected, the strata may have had a considerable extent in those directions.

As will be discussed later, it has been suggested that the Ouachita

[1] *Exploration and Survey for a Railroad from the Mississippi River to the Pacific Ocean*, Vol. iii, Pt. iv, p. 122.

[2] *A Geological Report upon the Fourche Cove and its Immediate Vicinity*, by W. Byrd Powell, M.D., Little Rock, 1842.

[3] *Proc. A. A. A. S.*, v, 1851, p. 199.

[4] *Second Report of a Geological Reconnoissance of the Middle and Southern Counties of Arkansas*, made during the years 1859–61, by D. D. Owen, Philadelphia, 1860, pp. 32, 33, 95, 110, 124.

[5] *Geol. Surv. of Ark.*, An. Rep. for 1888, Vol. ii, p. 262.

uplift is a remnant of a westward extension of the Appalachian chain. As this view presents certain difficulties, there has also been advanced the theory that that westward extension, if it existed, was to the south, possibly crossing the northern part of Louisiana. In such a case these beds may have been continuous with, though varying from, the Carboniferous exposures on the west of the Appalachians.

To the west the same beds run into the Indian Territory, and the Carboniferous is found as far west as the 100th meridian and in Texas as far south as the thirty-first parallel.

To the north the strata are thought to have been originally continuous with the strata just north of the Ouachita uplift.

Several attempts to prove this continuity were made, but without much success, though nothing to the contrary was found.

Direction and Conditions of Depositions.

Mr. Griswold, from his study of the novaculite area, came to the conclusion that the sediments with which he had to deal came from the south.[1] This was largely based upon the fact that the sandstones overlying the novaculite on the south are largely represented on the north by shales. Apparently the same fact is also to be observed in our area. This is shown by the difference in the topography: almost no shale being met with in the southern part of the region, and east and west valleys of any breadth are uncommon, while as the novaculite mountains are approached there are broad valleys with frequent exposures of shale. It was at first thought that this might be due to the strata as a whole having a slight south dip, so that the shales, which are low in the series, were not as fully exposed, but, as will be shown later, the proof is to the contrary. There also appears to be more shale exposed over the eastern part than over the western; but this is not marked enough to make one feel sure but that greater erosion may have had something to do with the difference.

V. General View of Structure After Folding.

In Fig. 1 is given a generalized section across the State in a north-south line through range 30 W.

[1] *Geol. Survey of Ark.*, Rep. for 1890, Vol. iii, p. 193.

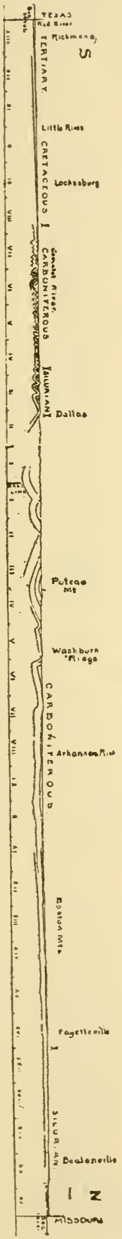


FIG. 1.—North-south section across the State of Arkansas through range 30 W.

This section has been compiled from observations by members of the survey.[1]

It shows a monocline on the north, a syncline in the centre, an anticline south of that, and a nonconformity at the southern limit.

The gradual change from practically horizontal strata on the north to highly folded on the south is also shown.

At the north Silurian strata are exposed, but on going south these gradually sink beneath Carboniferous deposits, to appear again in the great anticline of the Ouachita uplift. On disappearing again they continue but a short distance below the surface, until they and the overlying Carboniferous beds are covered by the gently dipping Cretaceous strata.

The section is given to show the relation of the area under discussion to the general section of western Arkansas. The line on which the section is made crosses the Ouachita uplift not far from its western nose, so that the Silurian outcrop is very small compared with what it would be on a north-south line further east, and likewise the Carboniferous outcrop south of the Silurian would be narrower in a section further east.

Historical.

None of the early writers on the geology of Arkansas seem to have made any attempt to work out the structure of the Ouachita uplift, or of the region immediately south of it.

Comstock.[2]—The first attempt to give system to the folds was made by Dr. Theo. B. Comstock

[1] Winslow, "Geotectonic and Physiographic Geology of Western Arkansas," *Bulletin Geological Society of America*, Vol. ii, pp. 225–242, Fig. 1; *Geol. Surv. of Ark.*, Rep. for 1891, Vol. iv, sections; *Geol. Surv. of Ark.*, Rep. for 1890, Vol. iii, section on Mt. Ida sheet; *Geol. Surv. of Ark.*, Rep. for 1888, Vol. ii, sections p. 126.

[2] *Geol. Surv. of Ark.*, Rep. for 1888, Vol. i, pp. 130–166.

North-South Sections in the Paleozoic Region South of the Novaculite Area.

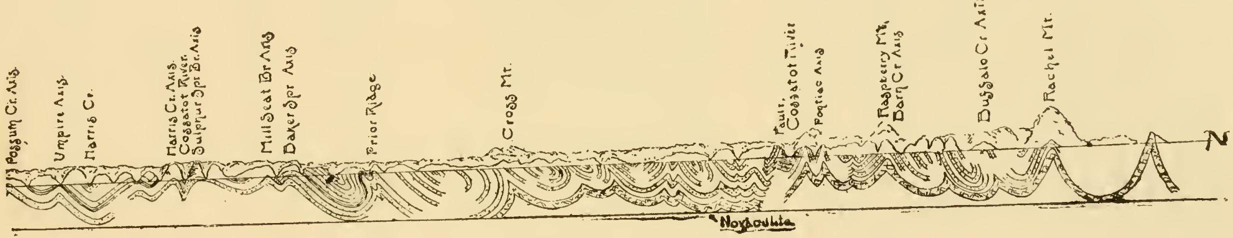


FIG. 1.—Section on Antoine Creek.

Horizontal scale: 1 inch = 2 miles. Vertical scale: 1 inch = 3000 feet.

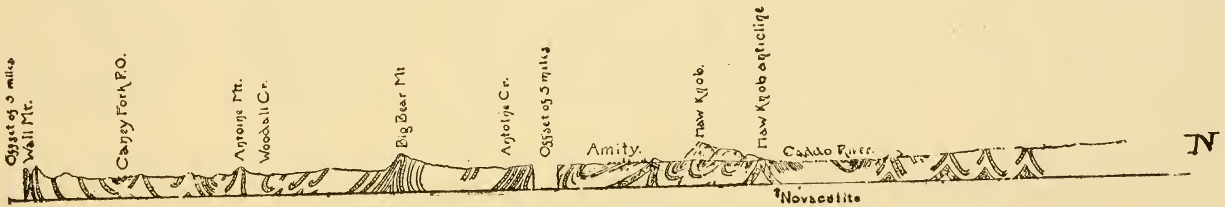


FIG. 2.—Section on Cossatot River and Brushy Fork.

Plate II.

FIG. 1.—Section on Antoine Creek (continued).

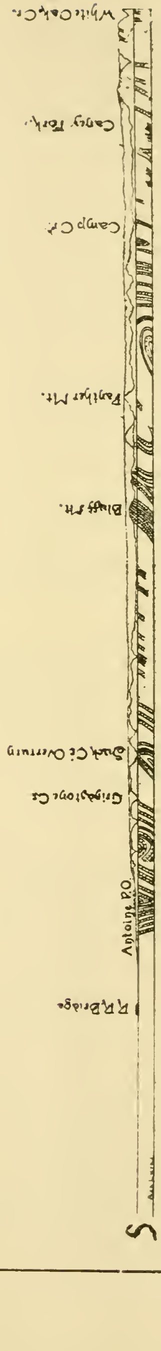


FIG. 2.—Section on Cossatot River and Brushy Fork (continued).

in 1887. He worked only in the western part and mapped out twenty folds and faults having a strike of N. 63° E., and connected with a similar number near Hot Springs.

That he should have found a uniform strike of N. 63° E. is difficult to explain, for the strike is extremely variable, seldom being the same in strata 100 yards apart. At most of the localities cited by him the strike lacks from 10° to 40° of being N. 63° E. The fact that so many ridges run "transverse to all geologic structural lines," he disposes of by introducing "some very powerful cause of greater moment than the twenty folds and faults which cut across the tract." But as a matter of fact these ridges are strictly conformable to the structure. The evidences of faulting which he found are all referable to the simple effects of erosion upon tilted beds, some of which are much harder than others. Considering the shortness of the time spent in the region and the obscurity of the structure, even at the best, and that outside of the river channels good exposures are rare and generally unsatisfactory, and that in the first of his field work, where the structure was more evident, the ridges have a trend of northeast-southwest, it is readily seen how he fell into error.

Subsequent Observers.—From that time until the work herein reported was taken up all the work done was such observations as different members of the survey made in traversing the region. These observations soon disclosed the errors of previous work, but did not reveal the number or closeness of the axes.

The Cross Sections.

An idea of the folding can be gained from the north-south sections on Pl. II (see p. 250).

The Antoine Section.—Fig. 1 gives a section through the centre of range 23 W. The part in township 6 S. is offset five miles, to a north-south line through Caney Fork P. O. The section in 7 and 8 S. is made along Antoine creek. Its striking general feature is the prevalence of south dips and overturned folds except at the ends. The first attempt to make this section gave only one doubtful north dip in shale. Further, the closeness of folding does not diminish to the south. The exposures are mostly sandstone, though in many cases the presence of shale can be inferred from the topography. In the segment through Caney Fork P. O. the topography is controlled by the structure, this being almost the only locality in the whole area where distinct anticlinal ridges with synclinal valleys between were found.

The Cossatot Section.—Fig. 2, Plate II, gives a section up the Cossatot river to the mouth of Brushy Fork, and thence up Brushy Fork to the north line of 4 S. The dip is north with many overthrows to the south. The southern end is not as closely folded as would be the case further east. The presence of one or more layers of shale or shaly sandstone has assisted materially in determining the structure. The exposures along the Cossatot are more numerous and the structure ascertainable with more certainty than on the Antoine. The novaculite is not exposed except at the extreme northern end of the section; but at many places it cannot be far from the surface, as it comes to the surface but a short distance east in Rachel and Raspberry mountains, and a short distance west in Cross mountain.

Direction and General Character of the Folds.

Eastern Sheet.—The structure of the eastern portion of the Lower Coal Measures area is obscure, and, as the map shows, but little understood.

This is due to three causes. Principally the prevalence of overturns; next, the fact that erosion has progressed until the streams are comparatively slow, with banks neither high nor precipitous, thus presenting few fresh exposures of rock; and again, the wide distribution of water-worn material which conceals everything.

From these causes the number of exposures found giving a dip and strike would average less than one to the square mile; in many townships they are as low as one in four to eight square miles. If a complete structural map of the region could be made it would probably show many more folds than are here indicated. At the eastern end of the map the anticlines and synclines all run nearly due west. In range 21 W. they all bend south, running 12° to 15° south of west. The Suck creek anticline and Bell's creek anticline are exceptions to this rule.

West of range 23 the folds in township 4 S. regain their due west course, the folds to the south maintaining the direction of 12° to 15° south of west. Of the anticlines shown, about one-half are overturns. Indications suggesting the existence of many other overturns were found, but they were not well enough marked to warrant their insertion.

The Western Sheet.—The western half of the area offered somewhat better facilities for working out the structure, due principally to the existence of four large streams running across the folds from north to south. These streams are rapid, and frequently they cut their way through the ridges in deep, steep-banked gorges for long distances. Rocky cliffs seldom occur, but the shallow creek bottoms afford many exposures of rocks. Between these streams exposures are as scarce as further east.

On the other hand the topography is of much service in suggesting structure. It is through the suggestions thus given by the topography that the connections between the exposures of axes have been worked out.

In townships 3 and 4 S. the strike of the folds is east-west or a little north of west. In 5 S. the strike is nearly always about due east-west. In 6 S. the strike is a little south of west, becoming due west as the Indian Territory line is approached. In 7 S. the slightly south of west strike is maintained.

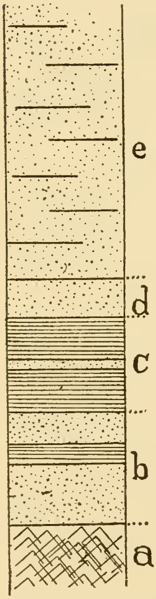


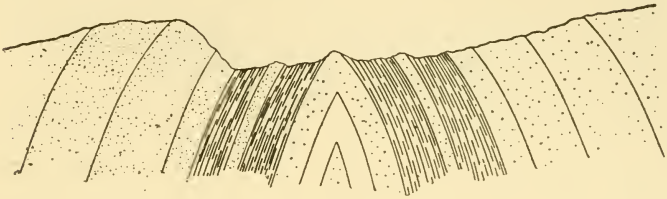
FIG. 2.—Columnar section of Paleozoic rocks south of the Ouachita mountains.

Thus it will be noticed that as the Indian Territory line is approached the fold tends to spread out like a partly opened fan. This results in the folds becoming more open toward the west. While the strata are closely folded or overturned on the Little Missouri and West Saline rivers, on the Cossatot they present more simple anticlines, and still further west, on the Rolling Fork, simple anticlines and lower dips are still more prevalent. This is especially true of the southern half of the region.

Where the dotted lines on the map suggest continuity of the axes, it is not necessarily implied that the anticlines are strictly continuous; as the complete structure, if known, might show two or more anticlines where only one is indicated, and these might be strung along in a line or be slightly out of line with the ends overlapping or running past each other.

Structural Types.

As introductory to tracing out the anticlines and synclines in the next chapter, it may be well to study briefly the effect upon the topography of such a section as here exists, when folded and the much eroded.



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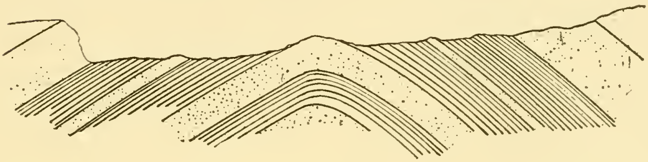

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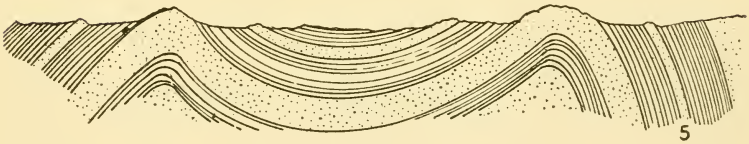

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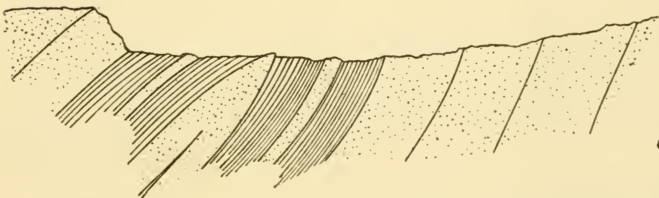

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Figs. 3–6.—Sections showing types of structure in the Paleozoic region of southwest Arkansas.

Let Fig. 2 be a very generalized columnar section, in which (*a*) represents the Silurian novaculites, (*b*) the sandstone immediately overlying the novaculites, (*c*) the variable thickness of sandstones and shales, (*d*) massive sandstones, and (*e*) the great thickness of soft and hard sandstones forming most of the section.

The topography developed upon these beds will depend to a great extent upon the character of the folds. In the case of a simple fold, such as are shown on Figs. 3 and 4, where erosion has eaten down until the hard sandstones are exposed, an anticlinal ridge will follow the axis with a valley on either side. Figs. 3 and 4 show the effect of the dip upon the width and character of the valleys. As a rule it is found that, of the ridges formed by the sandstones overlying the shales, the one on the side from which the principal drainage comes is cut down so as not to present an abrupt face. Fig. 5, shows the effect of two such anticlines close together.

Generally one side of the anticline is steeper than the other, as is suggested in Fig. 8, when this becomes overturned the effect is modified slightly, as is shown in Fig. 6.

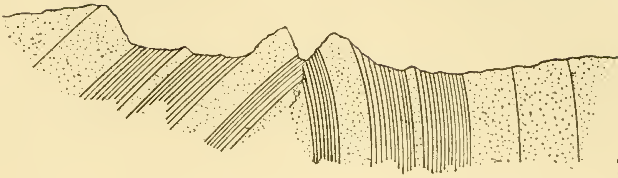
Where shale underlies the sandstone of the anticlinal axis, in time this anticline becomes breached (Fig. 7), and the topography resembles that of which the Wall mountain (Figs. 27 and 28) is an excellent example.

If erosion has not cut down to the underlying sandstone, the result will be the same, except that the anticlinal ridge is omitted and the valley will be narrower, possibly very much narrower. Such an anticline (Fig. 8), is difficult to locate accurately. This is a common type; it is illustrated by the Prairie Bayou anticline (Fig. 16).

Overturns of the kind shown in Fig. 9, are very difficult to recognize; the mere presence of the shaly layers is frequently the only suggestion of their presence. If the shaly layers were as surely located and as completely isolated as in the general section, Fig. 2, this could be relied upon; but, as shown by the columnar sections of Pl. I, it cannot be taken alone as a sure indication.

When the shales of the section are somewhat deeper seated they may not be brought within range of erosion; then the topography gives no clue to the structure. These conditions are illustrated by Fig. 10.

If an overturn occurs under such conditions as those suggested in Fig. 11, unless an exposure is found at the axis, it will generally pass unnoticed.



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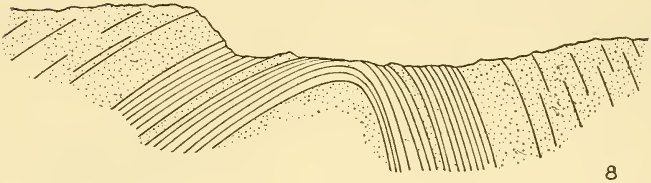

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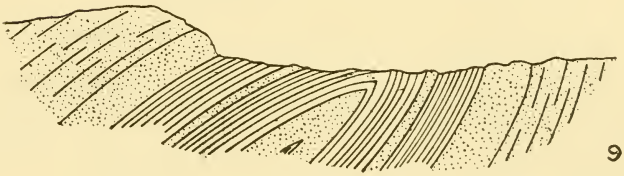

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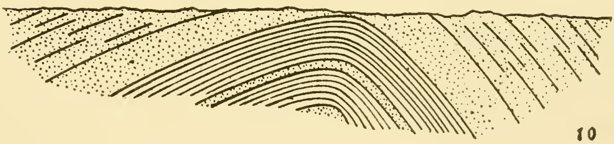

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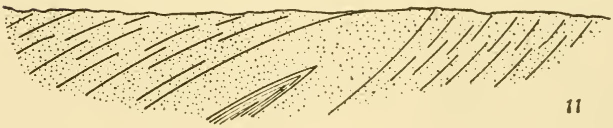

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FIGS. 7–11.—Sections showing types of structure and topography.

In each of these cases, while erosion is the apparent agency, the real determining factor is the comparative elevations of the original surfaces as compared with the average elevations of the surrounding region.

The anticlines may vary in height at different points, however, and a single anticline may represent almost every feature figured; for, as it begins low and gradually rises, it may expose at first only the upper sandstones, then the shales, then anticlinal ridges due to sandstones in or under the shales, as shown diagrammatically in Fig. 12. The anticlines which near the end may have low dips on either side, may be overturned near the centre or for much of its course.

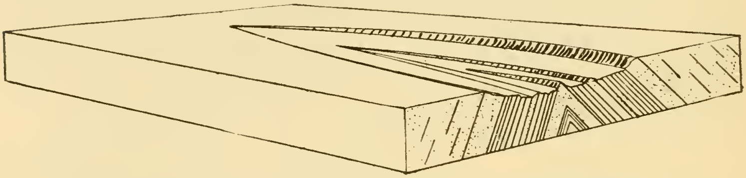
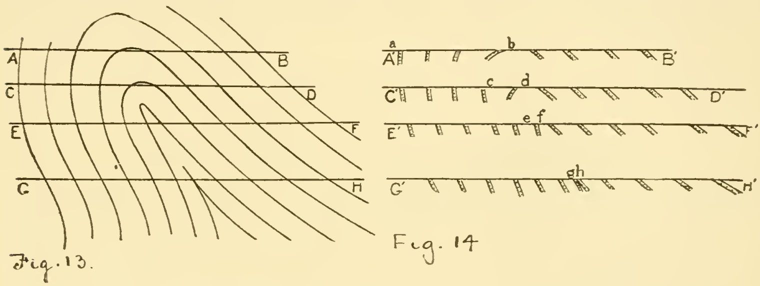


FIG. 12.—Diagram of topography at the end of an anticline.

Under the circumstances represented in Fig. 12 it would seem an easy matter to locate and accurately define the anticlines and synclines. As a matter of fact, almost no such evident structural topography is met with in the region under consideration.

While the topography is largely concordant with the structure, many disturbing elements enter which vitiate any conclusions that may be based upon topography alone. On account of causes to be spoken of later, the main drainage systems of the area are only slightly controlled by structure, their general trend being oblique or transverse to the strike of the folds. This results in a double series of valleys cutting each other at all angles; and through the same causes the main divides are also transverse to the structure and on these for a width of from half a mile to several miles the topography is usually not well enough marked to indicate structure. Many other local and minor causes, such as change in the character of the rocks, faulting, crushing of strata, constant variation in the character of the folds, and others enter as factors to complicate the topography. Though it is probable that the topography, if worked out in detail, would be found to be closely governed by the structure, modified by the factors mentioned, yet, when it is considered that, on account of the density of the forest, it is but rarely that the "lay of the land" can be made out for more than one or two hundred yards from the course pursued, it will be understood why, in a rapid reconnaissance like that undertaken, but little more than suggestions could be obtained from the topography. For these reasons the structure has, in no case, been assumed from the topography alone.

Overturns.—Overturns are a common feature of the area. In Fig. 13 is a simple overturn, and on the right side (Fig. 14) are shown the corresponding dips of beds at surfaces of different levels as AB, CD, EF, GH. Thus, in the case of A′B′ the axis is readily recognized; but remembering that no correlation of beds can be made, the section at that point would naturally be interpreted as an



FIGS. 13, 14.—Diagrams illustrating the structures shown by eroding an overturn to different depths.

anticline at *b* and a syncline at *a*. Such overturns are liable to lead to a confusion which can only be cleared up by careful detailed work.

In C′D′ and E′F′, the structure is the same, but is somewhat modified.

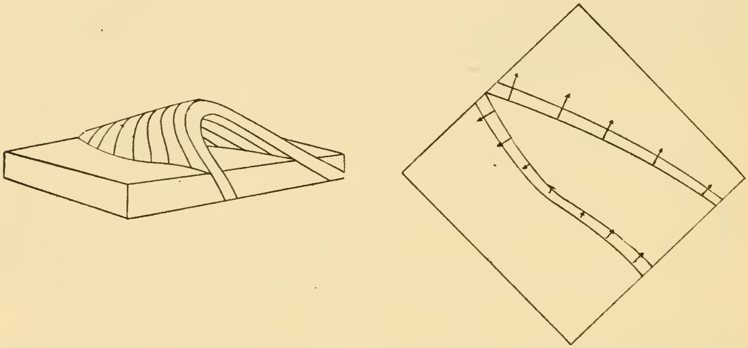
Most of the overturns found have been eroded so as to give exposures between those of C′D′ and E′F′. Sometimes there is a marked change in the dip on the two sides, as a low north dip on the upper side and a high north dip in the underfolded strata.

In such a case an overturn is suggested, and if an exposure giving a dip contrary to the general dip can be found, as *c* in C′D′, it has generally been considered as confirming the probable existence of an overturn at that point.

In many cases the only actual evidence obtainable is a single dip or two contrary to the general direction of dip. In such a case, the suggestion thus given may often be strengthened by the presence of shales, or of the thin bed of novaculite and silicious shale, all of which are believed to be low in the columnar sections and therefore, if exposed at all, would be near the axis. In a few cases the presence of the igneous rock or of parallel outcrops of the thin bedded novaculite and silicious shales was considered as a possible evidence of an anticlinal axis. In only a few cases could the actual continuity of the beds be traced.

When erosion has cut down to the level GH, it is next to impossible to recognize the axis unless a good exposure of rocks low in the series occurs directly in the axis.

When all these fail there has been tried successfully, in cases where the overturn is suspected, the plan of tracing an anticline into the disputed locality. Thus in Fig. 15 a layer of sandstone is



FIGS. 15, 16.—Diagrams illustrating the changes of dip and strike in the development of an overturned anticline.

represented as rising from a low anticline and merging into a high overturn. Were the block planed off, the outcrop would have some such shape as that shown in Fig. 16, on one side the dip remaining constant in direction, and probably not varying much in amount; on the side toward the observer not only is the outcrop curved somewhat, but the low dip at the further side gradually rises, finally becomes perpendicular, and then is reversed by the complete overturn of the fold.

In no case were continuous outcrops of that character found, but the plan used was to select some unusually hard layer or layers involved in the overturn, and to trace them partly by means of outcrops and partly by means of the scattered blocks on the surface, which resisting decay would indicate the presence of the hard layers beneath. Many of the overturns in the eastern part of the area were worked out in this way.

To resume, overturns may be suggested or located: (1) by the existence of anticlines to the east or west of a given locality; (2) by the prevalence over an unusually broad area of high dips in one direction; (3) by topographic relief; (4) by the exposure in parallel outcrops of deep-seated beds.

VI. Detailed Structure on the Eastern Sheet.

The detailed structure will be described under the artificial divisions made by the two map sheets of the area. The two general divisions of the eastern sheet may be studied under:

1. The Caddo Valley.

2. The area of drift, the Chalybeate mountain being taken as the northern edge of the area of drift.

Eastern Portion of Caddo River Valley.

The Caddo valley may be divided into an east and west portion, the dividing line being in range 22 W.

As will be explained more fully elsewhere, the topography of the portion of the eastern sheet north of the Chalybeate mountain, while broken up by divides and ridges into minor valleys, is a broad valley, differing in many ways from the country south of Chalybeate mountain.

Blakeley Creek Anticline.—The limits of this anticline were not definitely determined, but the ridge produced by it is between 100 and 150 feet high and five miles long, running from 4 S., 18 W., section 27, to 4 S., 19 W., section 26, along the south side of Blakeley creek. The ridge is of novaculite, but the novaculite bed is only poorly exposed. The ridge is serrated (as illustrated under Prairie Bayou anticline, Fig. 16), steep on the north side, the south side forming a water-shed to Prairie Bayou. It is highly probable that this anticline is continued further east, connecting with the one a mile and a half north of Social Hill.

Minor Anticlines.—Two minor anticlines were found in 4 S., 18 W., south half of section 29.

By minor anticlines is meant those in which the evidence of folding is meagre, or which could not be traced or other evidence of their existence found, or in which the thickness of the beds would indicate a small fold compared with the majority of folds. The evidence in most of these cases is only negative, but many of these so-called minor anticlines may prove to be quite as important as some which better exposures have disclosed more satisfactorily.

The Prairie Bayou Anticline.—Fig. 17 will give an idea of the structure of the Prairie Bayou anticline and of its accompanying topography, which may be taken as a type of the serrated ridges. The topography is a gentle slope draining from the top of the ridge next north leading to a long narrow valley, perfectly flat and covered by a deposit of novaculite gravel. This little valley is bounded on the south by a nearly perpendicular bluff 100 feet high, at whose base flows Prairie Bayou. From the top of the bluff the ground slopes gently south.

The anticline was first observed in the prairie from which Prairie

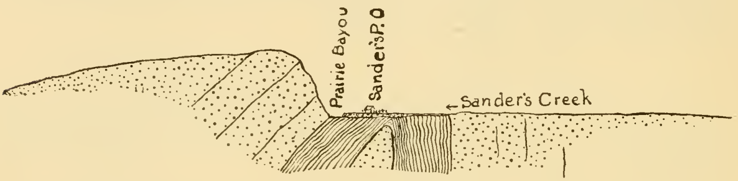


FIG. 17.—Section across Prairie Bayou anticline at Sanders Post-office.

Bayou takes its name in 4 S., 18 W., section 33. At that point it seems to be an overturn of the type C′D′, Fig. 14 (preceding chapter). From here it can be traced up the valley of Prairie Bayou, keeping close to the township line between 4 and 5 S., until in 4 S., 19 W., section 31, it becomes a simple anticline. The head of the east and west valley is at this point. It is crossed by the Arkadelphia-Hot Springs road in 4 S., 20 W., section 36, about an eighth of a mile north of the township line. The existence of several good springs on the axis along its western part should be noted. Westward from where it is crossed by the Hot Springs road the country is flat, and no indication of the axis is found until in 4 S., 20 W., section 31, where an anticline brings novaculite to the surface on the Big Hill creek. The ridge is 75 or 100 feet high and half a mile long; it is probably a continuation of the Prairie creek anticline.

Valley Fork Overturn.—In 5 S., 20 W., on the line between sections 3 and 4, De Roche creek cuts through a fifty-foot ridge a couple of hundred yards north of the crossing of the old Malvern-Murfreesboro road. The upper beds of the novaculite appear at the surface, but in a very small exposure. The structure appears to be an overturn. In 5 S., 20 W., section 6, on Big Hill creek, dips in the shale suggest that this overturn crosses the creek a little north of the half mile line. In 5 S., 21 W., section 4, on the Valley Fork of Point Cedar creek, half a mile north of Valley post-office, a seventy-five foot ridge is cut by the stream, exposing novaculite in thin ledges for a total thickness of 100 feet. The dip is perpendicular, indicating an overturn of the type G′H′, Fig. 14. The connection between this and the first exposure is doubtful, but having the same structure, and being in the same strike, it may be assumed that they are the same. West of the exposure on Valley Fork, the overturn can be traced into an anticline which is crossed by a branch of Point Cedar creek in 5 S., 21 W., section 7, northeast quarter. The strike from Valley Fork west is a little south of west. No trace of it was found further west, unless a small anticline on Cox's creek in 5 S., 22 W., section 9, southwest quarter be a continuation of it.

Minor Anticlines.—A small anticline is crossed by the Arkadelphia-Hot Springs road in 5 S., 20 W., in the south half of section 1; and another in 5 S., 20 W., north half of section 9, by De Roche creek.

Bayou Delile Overturn.—The Bayon Delile in its upper course runs east for some distance along the foot of a 75 or 100 foot ridge, finally turns south and cuts through the ridge in 5 S., 18 W., exposing an overturn in the gap with its overthrow to the south. This overturn shows again in perpendicular dips in 5 S., 19 W., section 15. It appears again to the south in 5 S., 20 W., just south of the northeast corner of section 16, on De Roche creek. It has not been found further west.

Minor Anticlines.—In 5 S., 20 W., section 16, close to the southwest corner, on a small branch of De Roche creek, is a small anticline, and again in 5 S., 21 W., section 13, is another or possibly a continuation of the first. In section 26, on the Caddo an anticline with a southwest strike shows very nicely. In 5 S., 22 W., southeast quarter of section 17 and southwest quarter of section 16, near the south section line, anticlines are exposed on Cox's creek. Also in the southeast quarter of section 15 a small anticline is exposed on a tributary of Cox's creek.

Through the centre of 5 S., 21 and 22 W., runs a belt about two and one-half miles broad in which the strata are nearly horizontal, the dip varying from 0° to 25° a little east of south.

De Roche Creek Anticline.—In 5 S., 20 W., the De Roche creek anticline is crossed by the Arkadelphia-Hot Springs road in the centre of the northeast quarter of section 36. Half a mile further west, where the axis is crossed by De Roche creek, Mr. Branner found it well exposed in the bank of the creek. The belt of north dips, a mile broad here, becomes narrow to the west until, as it enters 5 S., 21 W., it is less than a quarter of a mile broad, the axis being crossed by Big Hill creek half a mile from its mouth. It is crossed by the Caddo a mile west, in the northeast quarter of section 35, the strike being deflected a little south of west. It has not been identified further west.

The connection of the axis exposed on De Roche creek with that on Big Hill creek may be strongly questioned, even though the evidence obtained points that way. Theoretically it would be more satisfactory to connect it with the Big Hill creek anticline next described.

Big Hill Creek Anticline.—Just at the mouth of Big Hill creek in 5 S., 21 W., section 36, a ridge (140′) juts boldly out, the rock showing a dip of 88° S. As an anticline crosses the Caddo a mile west of this point in section 35, in the same strike, it is probable that the high ridge is in the axis of an overturn. This ridge is continued west of the mouth of Big Hill creek, forming a narrow divide between the Caddo and Big Hill creek which here runs east and parallel to the Caddo a quarter of a mile before running into it. The south side of this divide is for some distance composed almost entirely of a few bedding surfaces having a dip of 78° S., 2° W. For a mile or two north of where this anticline is crossed by the Caddo the structure is not clear, the dip varying rapidly; evidences of a fault are abundant, but the amount of throw could not be determined.

Caddo River Anticline.—The Caddo river anticline is thought to start in an anticline near the Ouachita river, a little south of the centre of 5 S., 18 W., which is crossed by the military road east of the centre of section 29.

In 5 S., 19 W., an overturn which has been assumed to be on the same anticlinal axis shows nicely on Waterhole branch, a tributary of De Roche creek, in the southern part of section 34. The overthrow is to the north, of the type G′H′, Fig. 13, and an approximate correlation of strata is possible. In the northern part of township 6 S., ranges 19 to 22 W., is a long shale valley just north of the Chalybeate mountain, occupied to the east by De Roche creek, further west by the Caddo river, and still further west by Brushy creek. In various parts of this valley there is much indirect evidence of an anticline or overturn, but, aside from those mentioned above, at only two places was direct evidence obtained, and that was not very satisfactory. In 6 S., 20 W., section 10, near the northwest corner is a round mound 80–100 feet high giving a dip of 75° N., 7° E. on the north side and 60° S., 2° W., on the south side; and in 6 S., 21 W., northeast quarter of section 12, at the bend in the Caddo there is some appearance of overturning. Scattered perpendicular dips in shales on about the same line would suggest that an anticline or overturn passed through the two points mentioned.

Western Portion of the Caddo River Valley.

In this division the structure is in several cases well displayed by anticlinal ridges which rise sharply from the broad valleys here predominating. The structures in these broad valleys is obscure, as might be expected, and in some portions the shale and interbedded sandstones have been twisted, faulted and jammed together until they defy all attempts to work out the original structure.

In 5 S., 22 W., Dr. J. P. Smith reports[1] four anticlines north of the Caddo river, the most southern of which is probably the same as the overturn giving the novaculite ridge north of Rock creek. It is probably this anticline which appears at the bend of the Caddo in 5 S., 23 W., section 17.

Sugar Loaf Creek Anticline.—In 5 S., 23 W., in section 1 or 2, near the section line, on Sugar Loaf creek is one of the few examples of an anticline where the axis is exposed, showing the beds closely bent on themselves. This exposure occurs at a road crossing where the creek makes a sharp turn to the east. It may be a continuation of one of the anticlines found by Dr. Smith.

Caney Fork Anticline.—In 5 S., 23 W., at the bend of the Caddo in section 11 is another case of an overturn showing well in the

[1] *Geol. Surv. of Ark.*, Rep. for 1890, Vol. iii, Mount Ida sheet.

axis.[1] The axis is crossed by the Caddo again in section 16 near the mouth of Caney Fork. It forms a fifty-foot ridge running along the south side of the Caddo. In section 16 it is crossed by the river again just south of where it turns east, and again a quarter of a mile further west in section 17. In 5 S., 24 W., there is an overturn in the northern part of section 24 showing poorly on and near the Amity-Rock creek road. This may be a continuation of the preceding, and if it is, it is probable that this anticline may be considered as running up the Rock creek valley near the middle east and west section line of the township. It is the determining factor in the structure of the northern part of Pine mountain.

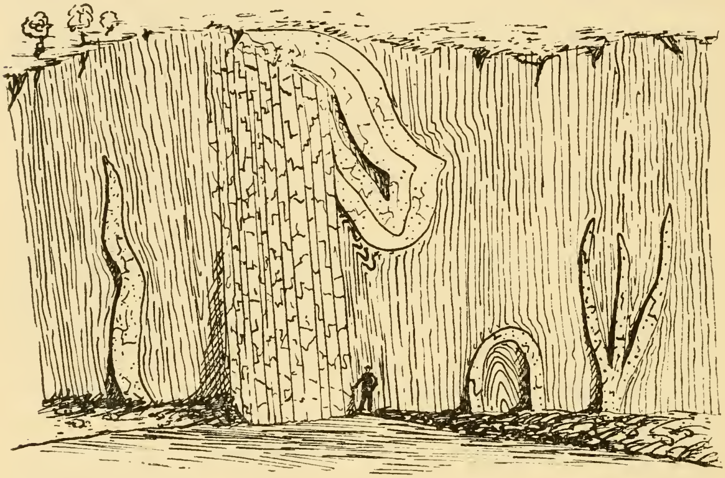


FIG. 18.—Contorted sandstone, shale, and novaculite exposed on the Caddo; 100 feet wide by 50 feet high.

In 5 S., 23 W., the northwest corner of section 21, on the Caddo, is one of the best exposures of the thin bedded novaculite and silicious shales and in the shales, on either side are good examples of contorted strata. Fig. 18 shows the wrinkling of these beds. There is also here a small but good example of a reversed fault having a throw of two and one-half feet.

Sugar Loaf Mountain Anticline.—In 5 S., 23 W., the northeast

[1] Photographs were obtained of many of the more interesting structural features of the region, but through an accident nearly three dozen of the best negatives were destroyed when it was too late to replace them.

quarter of section 14 is a sugar-loaf-shaped knob of novaculite about 200 feet high making a conspicuous landmark, as the country for a few miles in every direction is comparatively level. This may be a continuation of the Haw Knob anticline, the evidence being insufficient to decide the question.

The Haw Knob Anticline.—The Haw Knob anticline is first met with in a small ravine in 5 S., 23 W., about the centre of section 22. Half a mile southwest it is crossed by the Amity-Caddo Gap road, novaculite being exposed on either side of the road. Running southwest the novaculite produces a ridge which, though broken at two places, rises until at the western end, in the northeast quarter of section 29, where it is nearly three hundred feet high, it forks and ends abruptly. Farther west it appears to be continuous with an anticline on a branch of Antoine creek in section 30 northwest quarter and another anticline a mile further west in 5 S., 24 W., section 25, quarter of a mile north of the centre. The intermediate structure, however, is too broken to allow of direct connection being traced.

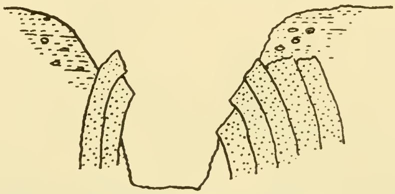


FIG. 19.—Section across a stream following an anticline.

This structure seems to show that Pine mountain, running east and west through the centre of 5 S., 24 W., is synclinal in its structure.

Minor Anticlines.—Between the Haw Knob and Amity anticlines the structure seems to be a syncline with the layers near the surface crumpled into a number of small folds. Along the Amity-Caddo Gap road in 5 S., 23 W., section 27 and 22, several anticlines are exposed. On the Caddo, in 5 S., 23 W., section 13, two overturns are exposed, one on the east bank close to where the Caddo crosses the south section line of section 13, and the other on the western side at the mouth of a small drain a little below where the Caddo crosses the west section line of section 13. The latter fold is a gaping anticline along which the stream flows. Fig. 19 shows a section across the fold. Exposures of igneous rocks are common in the region of these small anticlines.

Amity Anticline.—The Amity anticline is first noticed as a nose on the Caddo in 5 S., 23 W., near the centre of section 24. By means of a quartzite layer it was traced southwest into the novaculite ridge just north of Amity. It makes a low rise, exposing novaculite just east of the Amity-Hot Springs road in the southeast quarter of section 27; it forms the low ridge, seven hundred yards long, just north of Amity. This anticline can be traced by means of the large novaculite blocks strewn on the ground for a quarter

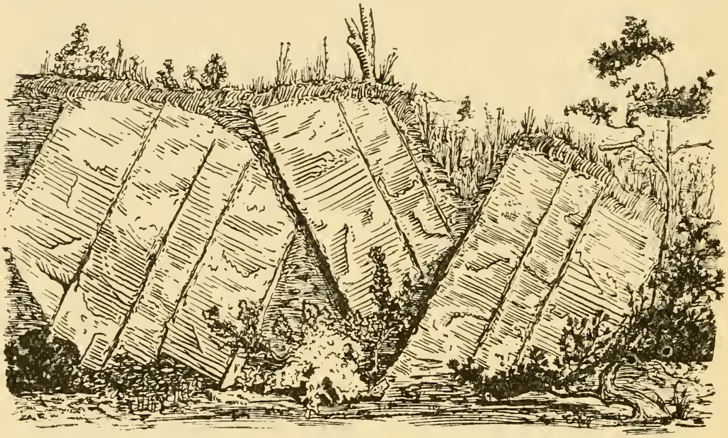


FIG. 20.—Faulted sandstones near Amity, Clark county (5 S., 23 W., section 30, S. E. quarter).

of a mile west of the end of the ridge along the direction of the strike. Where it crosses a small drain in section 33 the horizontal outcrops of the rocks are sharply bent, without fracturing, through an arc of 110°. In the northeast quarter of section 31, an anticline in the same strike crosses a tributary of the north fork of Antoine creek. It has not been distinguished further west. Near the last mentioned exposure is a curious example of faulting of the rocks; it is illustrated in Fig. 20. This fold is of interest as being the most southern anticline to bring thick bedded novaculite to the surface. The structure is overturned where the novaculite is exposed.

Minor Anticline.—In 5 S., 23 W., section 31, the southeast quarter, the dips indicate the existence of an anticline which is seen again in the same strike in 6 S., 24 W., section 2, where a small drain crosses the township line, near the north and south half-mile line of the section. This region between the Amity and Big Bear anticlines has been very badly crushed in 5 S., 23 W., sections 31 to 33. Fig. 21 is an example of crushing in shale exposed in a

FIG. 21.—Examples of crushed shale in 5 S., 23 W., section 33.

creek bottom in section 33, northwest quarter. In the southwest quarter of section 33, at the junction of two small creeks, is a fault with an offset in the outcrop of several yards, the sandstone layers being sharply jammed together and the shales tightly squeezed. Fifty yards from this point up the stream that enters from the west, the way the shales are crowded upon the end of a hard layer of

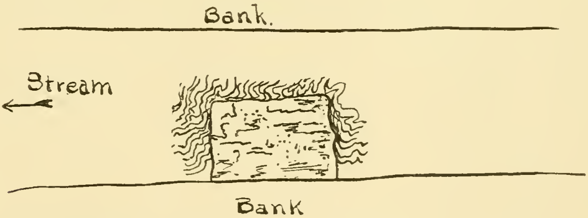


FIG. 22.—Shale in the bed of a stream showing secondary movement.

sandstone suggests that the movement may have taken place since the stream eroded away the part of the hard layer which is gone (see Fig. 22).

An Overturn.—In 5 S., 22 W., section 32, near the northwest corner are evidences (stronger in section 31, north of centre of section) of an overturn. The overturn follows up a little creek, the thin bed of novaculite and siliceous shale being exposed along the axis. In 5 S., 23 W., the axis strikes S., 20° W., across section 33 to 36, being readily traced by the fragments of novaculite over the surface. Passing into 6 S., 23 W., it follows the same course, the novaculite being exposed on both sides of the axis. In 6 S., 24 W., it crosses the north fork of Antoine creek just north of the crossing of the Alpine-Kirby road, where the anticline is no longer overturned.

Big Bear Mountain Overturn.—The Big Bear mountain overturn is almost in the strike of the last-mentioned one, but at the eastern end it seems to be deflected to the south. This anticline starts in 6 S., 24 W., section 11, southeast quarter, runs a little north of west for half a mile, then turns and runs S., 70° W., into 6 S., 25 W., on the western sheet, the southeast quarter of section 14 at the crossing of the Kirby-Murfreesboro road.

The Little Bear mountain, to be described later, is in this same strike, but its eastern end is deflected south, much as the eastern end of the Big Bear mountain is; otherwise the Bear mountains and the preceding anticline might be considered as a single anticline from the Caddo to the Little Missouri.

The Big Bear mountain anticline produces a high, sharp, irregular ridge. This ridge, which is about three hundred feet high, rises from a low, flat country and so makes a conspicuous landmark. It is the best example of an overturned anticlinal ridge in the region. The crest is sometimes as sharp as the roof of a house, the hard layer which makes this crest in many places forming the south flank of the mountain for a score or two of feet from the top with a dip of 67°. In several places where there is an exposed dip on the crest of ten or fifteen feet in length, springs start out from the very top of the ridge. In 6 S., 24 W., between sections 16 and 17, it is cut square in two by Gap creek.

While this may be due to the same causes that have allowed the main streams to run south across the strike of the beds, in this case the explanation seems to be that it is due to a backward cutting stream, an excellent example of which is a small stream on top of the ridge farther east. One of the little channels starting from a depression in the crest, as shown in Figs. 23 and 24, has cut its way along the top but on the side of the crest opposite to that down which it flows. This has continued until the channel extends for some distance along the top and has made a deep gap of the original depression from which it flowed. Given time enough, there will be formed at that point a gap cut clear to the bottom. The

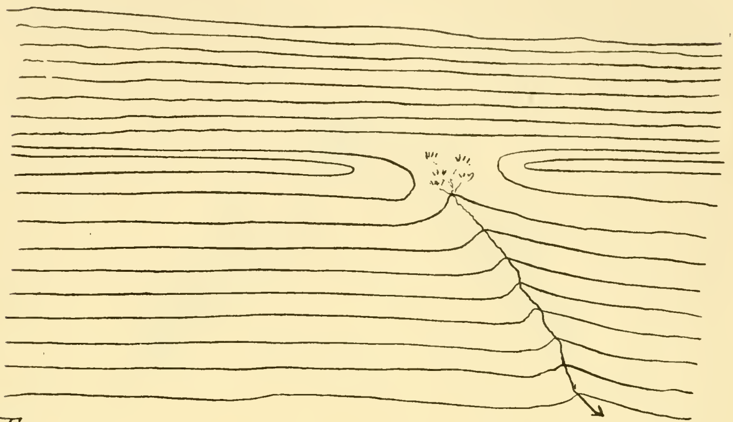


Fig 23 Early stage

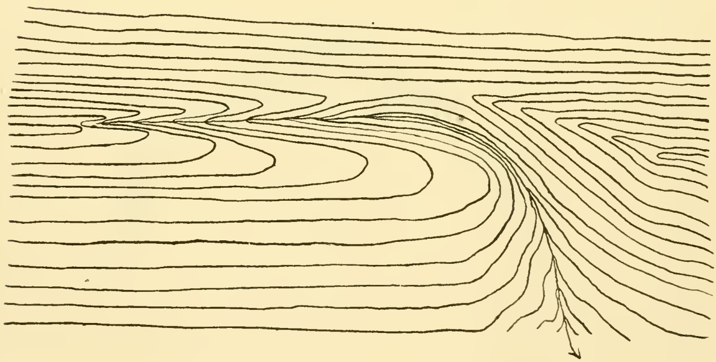


Fig 24 Later stage

FIGS. 22, 24.—Top of Bear Mountain, showing the development of a gap.

structure of this ridge can be seen at the gap, and at a few places along the top.

Alpine Anticline.—The Alpine anticline was first noted in 6 S., 22 W., Sec. 9, northeast quarter, in parallel outcrops of thin bedded novaculite and siliceous shale. It is crossed by the Alpine-Amity road half a mile northwest of Alpine. In 6 S., 23 W., it can be traced across sections 13, 14, 15 and 16, having a strike a

Fig. 25

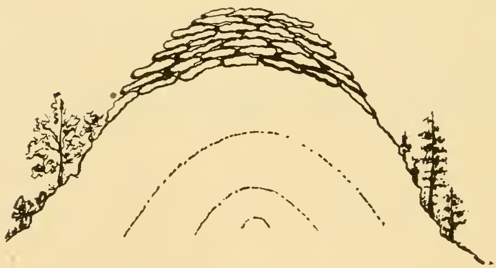


Fig. 26

FIGS. 25, 26.—Profiles of Antoine mountain, Pike county, Arkansas.

little south of west. It appears to be crossed by the Amity-Murfreesboro road in section 19, southwest quarter. It has not been found to the west.

Minor anticlines occur in the same township southeast quarter of section 8 and north half of section 17. Their extent is unknown.

Antoine Mountain Anticline.—Questionable traces of the Antoine mountain anticline appear in 6 S., 23 W., near the centre of section 22. In section 19, it forms a ridge extending westward into 6 S., 24 W., through the south half of sections 23 and 24, and probably forms the ridge across the township along the south side of Woodall's creek. The main ridge is two hundred to three hundred feet high, and is chiefly interesting on account of the anticlinal wall on its summit. This (see Figs. 25 and 26) is a low irregular wall about a quarter of a mile long, from the side resembling an old, ruined fortress. It varies in height and thickness. On the north side it is in places 15 to 20 feet high; on the south side it is frequently 40 feet high, and in thickness it varies from a wall from 3 to 6 feet thick to a mound-shaped pile of stones. The layers are not continuous, but the break is not due to faulting. The wall is composed of a pile of lenticular rock masses suggesting that while being bent the layers give way in small blocks, and these, under great pressure or tension, have elongated and assumed the shape and position as shown, and have been left behind by erosion. The theoretical consideration of this is taken up in VIII. The rock at this point is a firm white standstone showing little or no signs of metamorphism.

Minor anticlines.—There are two anticlines in 6 S., 24 W. One first noted in section 24, southwest quarter, was traced a little south of west to the centre of section 27. It makes a one hundred foot ridge and probably continues in the same course westward. The other one forms the low ridge just north of Caney Fork post-office, running from the centre of section 26 through the south half of section 27, and probably continues westward. Judging from the fact that traces of manganese show at the top of the last-mentioned ridge, the heavy novaculites, or the horizon at which they occur, cannot be far below the surface.

The Region of the Overwash.

As only four of the anticlines in the region of the overwash were definitely found at more than one locality, those four will be spoken of first.

The Mill Creek Anticline.—In 7 S., 21 W., northwest quarter of section 24, on Mill creek, an anticline is reported by Dr. O. P.

Hay[1] having a strike about 20° north of west. In this same strike Prof. T. C. Hopkins of this survey found an anticline on Bell's creek in 7 S., 21 W., section 18, northwest quarter, and also in 7 S., 22 W., section 11, southwest quarter, on Terre Noir creek, This anticline having a strike of N., 7° W., runs at a high angle to the general trend of the structure of this region.

Straight Mountain Anticline.—The relation of the Straight mountain anticline to the structure of the Chalybeate mountain to the east is not known; it is assumed as starting at Antoine creek in 6 S., 23 W., section 33, southeast quarter. It produces an anticlinal ridge, known as the Straight mountain, from two hundred to three hundred feet high, running a little south of west into 6 S., 24 W., section 36, and from this point is continued as the Wall mountain. It is broken at one point by Kirkland creek, which makes a gap in it.

Wall Mountain Anticline.—Wall mountain anticline is a continuation of the Straight mountain fold, and runs south of west to the Little Missouri river, which it reaches in 7 S., 25 W., southwest quarter of section 7. Starting from the Hot Springs road in 6 S., 24 W., section 36, for about a mile it forms an anticlinal ridge three hundred feet high; beyond this a little stream has cut its way into the anticline, and lowered it somewhat. This gives an excellent example of a breached anticline (Figs. 27 and 28).

In the sections given in Fig. 27, I shows the profile of the high unbroken ridge in the background toward the east; II, III and IV are successive profiles coming toward the foreground (westward), showing the cutting down of the centre of the ridge by the stream which originally cut in, and now drains by way of the gap shown in section IV; the full line gives a section on the west side of the gap. One of the interesting features of this ridge is shown in the illustration. This is a great wall, at one place about sixty feet high, crowning the summit of the north arm of the ridge for more than half a mile. It is composed of a layer of hard sandstone eight feet thick, rising perpendicularly. The manner in which it has withstood erosion is due partly to its hardiness and partly to its being so exactly vertical that detached masses simply rest in their places. The outcrop of the same layer of rock shows along the summit of the southern arm.

This weathering of the rocks in vertical walls is not uncommon

[1] *Geol. Surv. of Ark.*, Rep. for 1888, Vol. ii, p. 271.

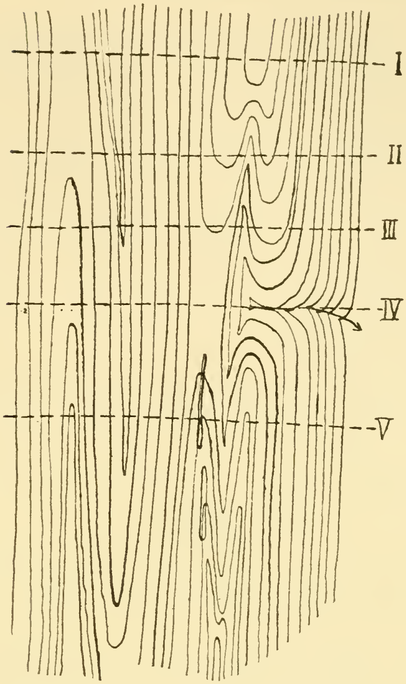


Fig. 27

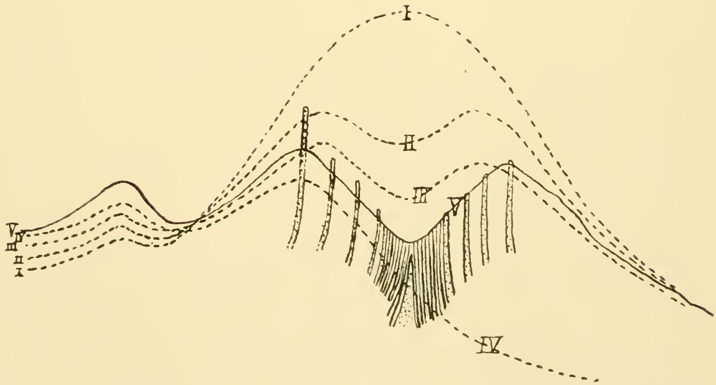


Fig. 28

FIGS. 27, 28.—Map and sections of Wall mountain.

on a small scale. In several places, where the heavy layers of sandstone are perpendicular at their outcrops, the topography is characterized by these irregular parallel walls, from two or three to ten feet high, running as far as the eye can reach.

Suck Creek Overturn.—The Suck creek overturn was only seen in 8 S., 23 W., first showing on a small creek in the southeast quarter of section 13. It is crossed by Antoine creek near the mouth of Suck creek in the southwest quarter of section 11, showing nicely in a small exposure on the east bank. It was traced up Suck creek about two miles; it appears to be an overturn all the way. Its strike is N., 65° W.

Other Anticlines.—The structure of the Chalybeate mountain was not solved, but the evidence suggests that it is an underthrown syncline, with the Caddo river anticline on one side, and on the south side an anticline of which no trace was found, unless there could be considered as such, perpendicular dips in 6 S., 22 W., section 13, near where the old Camden road leaves the Arkadelphia-Mount Ida road, or an exposure of shales apparently in the axis of an overturn in 6 S., 20 W., northern part of section 26, on the Caddo.

In 7 S., 21 W., section 10, an anticline is crossed by a tributary of Winfred creek in the northern part of the section, and another is crossed by Winfred creek in the southwest quarter. These have a strike of S., 65° W. In section 6 an anticline is crossed by Bell's creek in the southwest corner of the section with an east and west strike.

In 6 S., 22 W., section 36, an anticline was found at the end of a ridge; it probably continues to the Terre Noir, forming a ridge which runs a little south of west.

In 6 S., 23 W., there is an anticline or overturn just at the south township line in section 34 on the Antoine. It may be the cause of the valley of White Oak creek.

In 7 S., 23 W., it is probable that there is an anticline in the east and west valley running through the centre of sections 12, 11, 10, etc. Traces of manganese found near Story's store, section 10, southeast quarter, tend to confirm this supposition. In the centre of the township the strata for several square miles are so nearly perpendicular that a variation of a very few degrees gives the appearance of an anticline, so that it is impossible to tell which are anticlines and which are not. In section 22 is a large, flat area, and the evidence of an overturn here are somewhat stronger, chiefly the presence of shales with north and south dips. In the southern part of section 27, on the west bank of Antoine creek, a long bluff, seventy-five feet high, gives an excellent exposure of rock, and on either side of one point the layers bend toward each other in such a way as to suggest the axis of an overturn. Bluff mountain, a quarter of a mile farther south, also gives a fine exposure. An anticline probably crosses the big river-bottom in section 34, 7 S., 23 W.

In 7 S., 24 W., high dips and a ridge one hundred feet high, crossing Wolf creek near the centre of section 21, suggest the probability of an overturn with a strike S., 70° W. This is in the strike of an overturn on Prairie creek, to be described later.

VII. Detailed Structure on the Western Sheet.

Township 4 South.

Rachel Mountain Axis.—Rachel mountain is a novaculite ridge in the northern part of 4 S., 30 W., and has been described in the report on novaculite.[1] Its axis crosses the Brushy Fork of the Cossatot in 4 S., 30 W., section 5, southwest quarter. It ceases to be a novaculite ridge before reaching the Brushy Fork. In the same strike in 4 S., 32 W., section 1, half a mile south of Cove, an anticline is crossed by the line road, and traces of it are found in 4 S., 31 W.

Buffalo Creek Anticlinal Axis.—This axis is reported by Mr. Means[2] as crossing the Brushy Fork in 4 S., 30 W., section 7, the southwest quarter, near the mouth of Horn creek.

In 4 S., 31 W., it was noted again in section 12 and in section 10; the presence of igneous rock and the topography across that row of sections suggest its continuity in a due west direction.

In 4 S., 32 W., Mr. Means found the axis crossing the Old Line road near the middle of the section line between 11 and 12. A few uncertain dips indicate that it continues westward, and that it determines the Buffalo creek valley.

[1] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. iii, p. 262.

[2] Mr. J. H. Means, assistant geologist of this survey, worked up considerable of the area included in 4 and 5 S., 30 and 32 W. Most of the structure in 30 W. was gone over to get its connection and relation to the structure further east. That in 4 and 5 S., 31 and 32 W., is largely taken directly from Mr. Means' notes.

Mr. Means also reports an anticline or overturn on Brushy Fork in 4 S., 30 W., section 17, northwest quarter.

Barn Creek Anticline.—Raspberry mountain is a novaculite ridge crossing 4 S., 29 W., near the centre, and reaching the Cossatot in 4 S., 30 W., section 14, southeast quarter. Following this strike there is an anticline in sections 17 and 18, south part, which Brushy Fork crosses three times with an S-shaped curve, and in the southwest quarter of section 18 it is crossed by Rock creek.

Further west it is followed by Barn creek, and shows as an anticline near where the Old Line road crosses Barn creek in 4 S., 32 W., section 13.

To the west Mr. Means found this axis to be replaced by one a quarter of a mile further south. Barn creek swings south and follows the last axis quite closely across 4 S., 32 W.

Pontiac Anticline.—The end of a long novaculite ridge crosses the Cossatot in 4 S., 30 W., northwest quarter of section 22, just north of Pontiac post-office. It runs out as a ridge a mile to the west where it has a strike a little south of west. In this strike, in section 20, the northwest quarter, an anticline is crossed by Brushy Fork.

West of this point no anticline was found until 4 S., 32 W., section 19, where Mr. Means reports an anticline crossing Hickory creek near its junction with Buffalo creek.

Anticlines on the Cossatot.—In 4 S., 30 W., two small anticlines are crossed by the Brushy Fork in section 20, one near the north section line and the other a little more than a quarter of a mile further south.

About a quarter of a mile from the south side of section 20 (4 S., 30 W.), Brushy Fork and the Cossatot are separated by a high but narrow neck of land, ten to twenty yards wide. They diverge, however, and flow together a mile further down. On the Cossatot side of this neck is exposed the fault shown in Pl. VIII.

This same fault shows again in section 21 at the first bend in the Cossatot south of Pontiac post-office. It is really a double fault, as shown in the Cossatot section on Pl. I.

In the same township, section 30, near the half-mile line, the Cossatot crosses an overturned anticline. A quarter of a mile below, in the southwest quarter of section 29, the Cossatot crosses another anticline, and near the south section line of section 29, it crosses still another. This last anticline is in the same strike as one crossed by Baker creek near the south section line of section 25 of the same township. In section 31, southeast quarter, the Cossatot crosses an overturned anticline, as shown in Pl. II.

Hickory Creek Anticline.—In 4 S., 31 W., section 26, southeast quarter, an anticline is crossed by Flat creek. In this same strike Mr. Means reports an anticline crossed by the Old Line road in 4 S., 32 W., section 25, southwest quarter. Going westward it forms a low ridge which separates the two branches of Hickory creek. This fold was not seen west of sections 28 and 33. An anticline was found by Mr. Purdue in 4 S., 29 W., section 35.

A few other minor folds were noted.

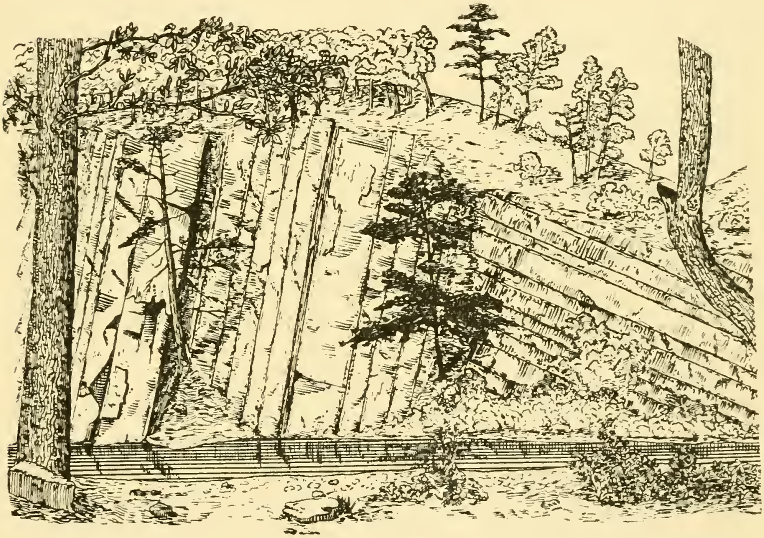


FIG. 29.—Fault on the Cossatot near the Mouth of Brushy Fork (4 S. 30 W., Sec. 20).

Structure in Township 5 South.

Novaculite Ridges.—As the novaculite ridges have been described in detail in the report on novaculite[1] they will only be mentioned here. In 5 S., 25 and 26 W., the northern two tiers of sections are occupied by novaculite ridges; Brook's mountain, North mountain, Warm Spring mountain, Line mountain, and others. In 5 S.,

[1] *Geol. Surv. of Ark.*, An. Rep. for 1890, Vol. iii, Chap. xiii.

27 W., the end of Line Mountain crosses sections 1 and 2, and Raven mountain, with a south of west strike, enters sections 4 and 5. Between sections 5 and 6 it is cut by the Little Missouri river, the anticlinal structure showing, distinctly. West of the Little Missouri it strikes a little north ot west, and under the name of Prairie mountain crosses the northeastern section of 5 S., 28 W., gradually entering 4 S., 28 W. It is crossed by the Saline at Moore's mill, in section 31, and it comes to an end a mile or two further west.

In 5 S., 31 W., a novaculite ridge, called the Cross mountain, rises in section 2 and runs out at the Line road in 5 S., 32 W., in the northern part of section 1.

In 5 S., 32 W., the southern part of section 1, are two short novaculite ridges in the same strike. The Line road passes between the two through what is known as "the gap." In the southeast corner of section 2 another ridge rises and runs west to the gap at the head of West creek, in the southwest quarter of section 3. West of this gap it rises to a height of 450 feet, and is known as Potato hill, then it runs a little south of west and passes out of the State at section 7. Between sections 11 and 14 the South mountain begins, strikes west for two miles, where it is cut by the head waters of Cross creek, then runs south of west and passes out of the State in section 18. These ridges continue west into the Indian Territory, but how far and how important they become is not known.

Ball's Branch Anticline.—Ball's Branch anticline is crossed by the Saline river in 5 S., 28 W., section 6, near the centre of the section.[1] In 5 S., 29 W., this same anticline passes through sections 1 and 2, crosses Harris Fork in section 2, northwest quarter. Though the anticline was not found to the west, ridges which occur in its strike suggest that it, at least, continues across the northern edge of 5 S., 29 W.

In 5 S., 30 W., the Cossatot crosses an overturn near the north section line of section 6.

The Watkins' Mill Overturned Anticline.—The Watkins' mill fold is a simple anticline where crossed by the Saline in 5 S., 28 W., section 5, on the south section line.

Where it is crossed by Harris Fork at Watkins' mill, in 5 S.,

[1] Practically all the structure of ranges 28 and 29 W. was worked out by Prof. A. H. Purdue, Professor of Geology at the Arkansas Industrial University, formerly assistant on the Geological Survey.

29 W., in the southeast corner of section 3, a recent exposure made in the bank shows the strata making a complete overturn. Prof. Purdue reports this to be an unusually fine illustration of an overturn. The overthrow is to the south. Though this fold was not found further west, the monoclinal ridge just north of it was traced across the township, indicating that the anticline continues across the township with a strike a little north of west.

In 5 S., 30 W., there is probably an overturn in sections 6 or 7 —an eastward continuation of the Cross mountain. Only north dips were found, however.

Minor Anticlines.—In 5 S., 28 W., section 8, northeast quarter, the West Saline crosses an anticline a little below Lance's mill, and in the centre of the southeast quarter of the same section there is another one. In 5 S., 29 W., there were found, corresponding to these two anticlines, two doubtful anticlines on Harris Fork; one a quarter of a mile south of Watkins' mill in section 10, and the other a quarter of a mile north of the southwest corner of section 11.

Prior Ridge Anticline.—In 5 S., 27 W., the structure and topography suggest an overturned anticline in the northwest corner of section 17. It is overthrown to the north. At the Little Missouri it is hidden in bottom land, but a short distance west of that stream it makes a ridge between White Oak creek and Clover creek, which gives evidence of anticlinal structure. This ridge was traced a little south of west to the Saline, where the structure is anticlinal. From the Saline to Harris Fork it could not be traced, but an anticline crossed by Harris Fork in 5 S., 29 W., northeast quarter of section 15, is in the same strike and may be the same axis. This last anticline may also be on the same axis as an anticline on Moore's creek, section 16, northwest quarter; the intermediate topography exhibits no clear structural relations.

An anticlinal ridge extends from Moore's creek to the Cossatot; the anticlinal structure is shown where it is cut by Moore's creek in 5 S., 29 W., northwest quarter of section 16. The ridge then runs a little north of west to 5 S., 30 W., southwest corner of section 12, showing the anticlinal structure north of Eldridge postoffice in 5 S., 29 W., section 18, northern part.

In 5 S., 30 W., it is known as Prior's ridge, and it runs due west from section 12, the anticline showing where cut by Baker creek in the southwest corner of section 11, and as an overturn where cut by the Cossatot in section 7, southeast corner. From the Cossatot westward the shales which are exposed on the Cossatot have been eroded, producing in 5 S., 31 W., the Prior creek valley. This anticline, if produced into 5 S., 32 W., will join with the South mountain anticline.

Minor Anticlines.—In 5 S., 29 W., a small anticline is crossed by Harris Fork in section 15, the southeast quarter. In 5 S., 30 W., parallel outcrops of the thin novaculite seem to indicate an anticline or overturn in section 17, northeast quarter. In 5 S., 32 W., section 16, northwest quarter, two small anticlines are cut by Cross creek.[1]

Baker Spring Ridge Anticline.—In 5 S., 27 W., the Little Missouri river crosses an anticline in the northwest quarter of section 16. This anticline runs a little south of west, forming a two hundred foot ridge between Clover creek and James creek. In 5 S., 28 W., it is crossed by the Saline in the southeast corner of section 16; from this point it runs due west, being crossed by Harris Fork in 5 S., 29 W., section 15, in the southeast corner. On the south side of the anticline, between Harris Fork and Moore's creek, is a two hundred to two hundred and fifty foot ridge, highest at the Harris Fork end. It passes south of Baker Spring in 5 S., 20 W., section 14, southeast corner, and where cut by Baker creek, in section 15, southeast corner, there is one of the best exposures of an anticline in the whole area.

Going west the ridge made by this fold rises to a height of two hundred to two hundred and fifty feet. It is crossed by the Cossatot in the southeast quarter of section 17. In the centre of section 17 is the fine exposure known as the Falls of the Cossatot. The topographic effect of these heavy ledges is seen in the long high ridge between Prior creek and Cow creek, which runs across 5 S., 31 W. In the southeast quarter of section 14 and in the same strike to the east, shales are exposed structurally identical with the shales just under the heavy novaculite exposed in the Prairie mountain anticline on the Little Missouri river. Baker Sulphur Springs issue from this shale.

West of the Cossatot Mr. Means found this anticlinal axis in 5 S., 32 W., section 13, southeast quarter.

Mill-site Branch Anticline.—In 5 S., 27 and 28 W., the Mill-site branch anticline was not surely found, but the presence of thin-bedded novaculite shales, horizontal dips and the topography sug-

[1] All structures on Cross creek were worked out by Prof. A. H. Purdue.

gest its existence parallel to, and a little over a quarter of a mile south of, the last-described axis. In 5 S., 29 W., it forms the valley of Mill-site branch through sections 23 and 22. At the mouth of the creek a small fall in Harris creek offers some water power. North and south of the Mill-site branch valley are high ridges, the southernmost one being synclinal in structure. From Harris Fork to the Cossatot in 5 S., 30 W., section 21, northwest quarter, the continuity of the structure is clearly defined by the long ridge north of the Harris Fork valley and ridges between Baker creek and the Cossatot in 5 S., 30 W. Mr. Means crossed the anticline in the northwest quarter of section 20, but it was not found further west in 5 S., 31 and 32 W. To the east of the Little Missouri no anticlines were found in this strike, but the topography of the Pine mountain in 5 S., 26 W., in section 15, south of Lodi post-office, gives every evidence of being an anticline, probably an overturn.

The ridge, which, for the most of its length, is not conspicuous, here becomes one hundred and fifty feet high, and this anticline again may be in the same axis as the overturn south of Rock creek post-office.

Blocker Branch Anticline.—Corresponding in strike with the overturn in the south part of Pine mountain in 5 S., 24 W., as carried out by the topography, is an overturn on the Little Missouri river in 5 S., 27 W., sections 21–23. This overturn is visible at a number of places along the river, the bending showing nicely at the foot of the road just north of Mr. Logan's, north of the centre of section 22. This fold is remarkable for the low dip on the south side.

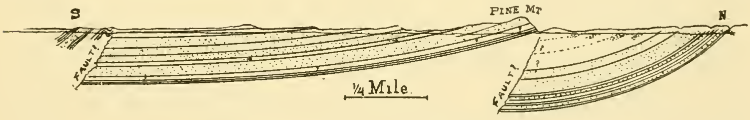


FIG. 30.—North-south section along the Little Missouri river.

The exposure as given in Fig. 30 is two miles long. Pine mountain, shown in this section, is an abrupt ridge on the northern edge of sections 26 and 27 over two hundred feet high, though it maintains this height for only a mile or two to the west. There is probably a fault just north of this ridge, as seen in the section in Fig. 30.

West of the Little Missouri the course of the anticline is shown by the low ridge north of Blocker branch. But it could not be traced to the Saline river, and, as the structure there is quite different, it will be considered as confined to 5 S., 27 W. Attention is called to the northeast direction of the streams in sections 28–30.

Sulphur Spring Branch Anticline.—The structure in 5 S., 29 W., is not clear, but the topography and the shales go to show that the Blocker branch axis is followed by the Sulphur Spring branch anticline in sections 22–24, and from Harris fork to Baker creek the shale it exposes is a factor in the breadth of the valley of Harris creek.

In 5 S., 30 W., from Baker creek west, this fold forms a two hundred and fifty foot ridge, the structure showing at several places where cut by ravines. In this ridge the shales appear well up in the ridge, while blocks of novaculite lying on the highest point of the ridge indicate the presence of the layer of thin novaculite.

Reverting to the question of the age of this thin bed of novaculite, and referring to section 2, Pl. ii, it is readily seen that if the novaculite occurring thus on top of this ridge be Lower Silurian, as the main body of novaculite is supposed to be, we should have at this point a belt from one to two miles broad in which almost nothing but Silurian rocks are exposed.

To the west of the Cossatot no anticline was noted in this strike, but it is probable that it influences the topography of Cow creek valley in 5 S., 31 W.

Harris Creek Anticline.—The Harris creek anticline is crossed by the Saline in 5 S., 28 W., at the north section line of section 28. Thence it passes nearly due west, helping to form the high ridge south of Sulphur spring branch, in 5 S., 29 W. It then becomes part of the Harris creek valley, and is followed by that creek most of the distance. It is crossed by the Cossatot in 5 S., 30 W., at the north section line of section 26. The structure of the fold is well shown where cut by the Cossatot. From this point it trends due west, forming a high ridge for over two miles on the south side of the Cossatot, which, for that distance, flows through a deep narrow gorge between this ridge and one just north of it made by the Sulphur spring branch anticline. The river flows in the trough of the syncline between these two anticlines, in places being walled in by parallel, almost perpendicular layers of sandstone, which give it the appearance of a canal. There is an anticline on this same axis in 5 S., 31 W., section 26, northern part.

Minor Anticlines.—In 5 S., 28 W., an anticline is crossed by the

Saline river in section 28, northwest quarter, a quarter of a mile south of the Harris Fork axis. At the same distance south of the Harris Fork axis, where it is crossed by the Cossatot in 5 S., 30 W., is an anticline corresponding to the one exposed on the Saline.

In 5 S., 32 W., a small anticline is exposed on the Rolling fork in section 25, a little south of the centre of the section, and a quarter of a mile further south another one is crossed by the same stream. In the strike of these two anticlines, two anticlines are crossed by Cross creek in section 29, southwest quarter. They may therefore be considered as on the same axis.

Umpire Anticlinal Axis.—In 5 S., 28 W., the Umpire anticline forms a ridge in the northern part of sections 34 and 33, and is crossed by the Saline in the northwest of the northwest of section 33. Further west in section 31 it is crossed by a small stream in the southwest of the northeast, near an old mill. In 5 S., 29 W., it is indicated by the dip in section 35.

In 5 S., 30 W., it is crossed by the Cossatot in the centre of the northwest quarter of section 36. In 5 S., 32 W., section 32, southwest of northwest, an anticline is crossed by Cross creek. Though in the same strike this can hardly be assumed to be a continuation of the anticline further east.

Possum Creek Anticline.—In 5 S., 29 W., an anticline runs close to the south township line. In 5 S., 30 W., sections 35 and 36, the Cossatot crosses the same anticline near the south township line. The topography, which east of the Cossatot is a valley, to the west becomes a prominent ridge. It runs west along the township line south of Possum creek and is found to be an anticline where crossed by the Rolling Fork just south of the township line, in 6 S., 32 W., section 2, at the ford of the Eagletown road. Igneous rock is exposed in the axis at the last named place. There is an anticline crossed by Possum creek in 5 S., 31 W., section 35, northwest of southeast, but the topography shows that it cannot be on this axis.

Other Anticlines.—In the Carboniferous portion of 5 S., 25 and 26 W., the structure is but little exposed. The streams seldom have deep channels and the dips found are universally south, except for a quarter of a mile along Bear creek in 5 S., 25 W., section 34, northwest of northwest. This last mentioned dip discloses the only anticline definitely known in the township, though in some places the bending of the rock suggests overturns. Slickensides abound all over the region, but there is an unusually fine example of them in 5 S., 26 W., section 24, southeast quarter, where the edges of the heavy layers having a dip of 25° are polished horizontally. Such cases are common and are evidence of faulting, even though no other testimony be obtained. In this case Self creek has followed the fault and has been carried three-quarters of a mile eastward.

In the same section, a little south of the centre, the rocks and topography suggest an overturn with a strike of about S., 73° W. In 5 S., 26 W., section 28, southwest quarter, on Rock creek in the same strike, the rocks are sharply curved, and further west in section 31, southwest of northwest, an anticlinal axis shows well on the east branch of the Little Missouri. The structure at this last exposure is shown on the left of Fig. 30, the fault being introduced to account for the sudden change of dip.

In 5 S., 27 W., section 25, southwest of southeast, on the Little Missouri river, a heavy mass of sandstone, showing no bedding and of unknown extent, appears to have been forced up or down through a thick exposure of thin-bedded shaly sandstone. The great quantity of slickensides in every direction in it seems to preclude the idea of its being an unconformity.

The Structure in Township 6 South.

Little Possum Creek Anticline.—In 6 S., 28 W., the Little Possum creek axis is crossed by the Saline river in section 8, northwest of the northwest. It is exposed next in 6 S., 30 W., forming a ridge south of White Oak creek and showing well its structure at the end of the ridge in the northwest of the northwest of section 10, and also in section 9, northwest quarter. In 6 S., 31 W., this axis is followed by Little Possum creek. In 6 S., 32 W., it is crossed by the Rolling Fork in section 12, northwest quarter.

Galena Synclinal Axis.—Just south of the last described anticlinal axis and parallel to it are two other anticlines. The northern one is crossed by the Saline river in 6 S., 28 W., section 8, southwest of northwest, the other one is crossed by the same stream half a mile further south. In 6 S., 29 W., only the southern one was found, following the south section line of sections 10, 11 and 12. Galena post-office is on the syncline between these two anticlines. The two folds form a single flat-topped ridge which slopes off to the south very gradually. In 6 S., 30 W., the northern one is crossed by the Cossatot in section 9, southwest quarter, and the southern anticline in section 17, northwest quarter. Further west their presence is indicated only by finding outcroppings of igneous rock in 6 S., 32 W., section 9, southeast of southeast, in the strike of the northern anticline and in the strike of the southern one in section 14, northwest quarter, on Rolling Fork and on the bluffs above.

Brushy Branch Anticline—The Brushy branch anticline is the northernmost of the three anticlines that are crossed by the Little Missouri river in 6 S., 27 W., section 12. It is in the northeast of the northwest quarter, nicely exposed in shales, and is overthrown to the north. Just north of it in section 1, where the river runs southwest, a syncline shows on the east bank. It was noted in section 9, northeast of southeast, south of Brushy branch, with a strike a little south of west. Following the topography across 6 S., 28 W., an anticline is crossed by the Saline in 6 S., 29 W., section 24. From here the axis is supposed to run south of west across 6 S., 29 W. Then turning west it crosses 6 S., 30 W., connecting with the anticline crossed by the Cossatot, in section 30, the southwest quarter of the northeast quarter. In section 29 this anticline forms a high ridge north of Sweeney's creek. Due west of this another anticline is crossed by the Rolling Fork in 6 S., 32 W., sections 25 and 27, and again in section 30, northeast of the northwest, an outcrop of igneous rock indicates its presence.

The White Oak Creek Anticline.—The White Oak creek anticline is the second of those crossed by the Little Missouri in 6 S., 29 W., section 12. The south side of the anticline appears, as a small monoclinal ridge, the single layer which forms the body of the ridge being bent sharply at the top. It then forms the ridge which runs south of west, south of White Oak creek and the Brushy fork of the Saline. This ridge, while not sharply defined, is quite a high one, forming a watershed between Brushy Fork and the drainage to the south and southeast. In 6 S., 29 W., it is crossed by the Saline in the southeast quarter of section 26, and again in the northeast quarter of section 33, the structure here appearing to be an overturn overthrown to the south. It then turns due west, forming a broad flat-topped ridge across the southern part of 6 S., 30 W., south of Hunter's creek, being crossed by the Cossatot in section 31, northeast quarter, the anticline still being overthrown to the south. The high ridge between Sweeney's creek and Hunter's creek is a good example of a synclinal ridge. From the Cossatot the axis strikes a little south of west, the overturn flattens down and is crossed by the Rolling Fork in 6 S., 32 W., the southwest of the southwest of section 34.

The New Hope Anticline.—The third axis is crossed by the Little Missouri in 6 S., 27 W., in the southwest quarter of section 12. It appears to form the ridge upon which the western half of the Star-of-the-West and New Hope road is built. The lack of marked topography prevented its being followed further west.

The Self Creek Overturn.—In 6 S., 26 W., section 11, northeast quarter, is a good example of an overturn of the type shown by E′F′ in Fig. 14. This is probably a continuation of an anticline crossed by Bear creek at the north township line of 6 S., 25 W., section 4. The strike would carry it south of west to a probable overturn in the top of Pine mountain south of Star-of-the-West, 6 S., 27 W., section 13. But the topography does not sustain that view. The steep north side of the Pine mountain in 6 S., 26 W., has a strike a little north of west. No outcrops were found in this part of the ridge and all those found in adjacent territory have a strike a little south of west, so that the ridge, though so marked, may not conform to the structure in 6 S., 26 W. West of Star-of-the-West the Pine mountain is deflected until it strikes about southwest, the strike of the outcrops being the same. It ends abruptly at Fallen creek.

The Gentry Overturn.—South of Gentry post-office is a ridge two miles long, starting in a high knob at the southwest corner of section 7, 6 S., 25 W., and maintaining a height of one hundred and fifty feet in a south of west direction to the Little Missouri river. This ridge gives the appearance of being an anticline overthrown to the north.

Bear Creek Anticlines.—An anticline is crossed by the Kirby-Murfreesboro road in 6 S., 25 W., in the southwest corner of section 11. In the northeast corner of section 19, on a small tributary of Bear creek, the dip suggests the presence of an overturn overthrown to the north; this may be a continuation of the Little Bear mountain overturn. In 6 S., 26 W., the Little Missouri crosses an anticline or overturn in section 24, the northwest quarter.

The Little Bear Mountain Overturn.—The Little Bear mountain overturn is in 6 S., 25 W. It begins in section 22, eastern part, at the Kirby-Murfreesboro road. Rising abruptly to a height of about three hundred feet it runs at first northwest, then gradually swings around until it runs a little south of west and ends abruptly in the northwest corner of section 21. On the top of this ridge the rocks, though not rising into a wall, present very much the same peculiar structure as on the top of Antoine mountain. The sandstone on top of this ridge, when not examined closely, bears a striking resemblance to novaculite in color, fracture and general appearance. The structure is an overturn overthrown to the north.

Chimney Rock Anticline.—In 6 S., 26 W., section 36, southwest of northeast, a mass of rock juts out from the east bank of the Little Missouri, forming a perpendicular cliff one hundred and forty feet high and tapering from a broad base to a narrow top. It is known throughout the region as the "Chimney Rock." The dips along the river for a mile or two are within a few degrees of perpendicular, and so give no clue to the structure, but the most probable explanation is that the "Chimney Rock" is in the axis of a closely pressed anticline. Several anticlines may be crossed by the river in sections 25, 26 and 36 without their presence being recognized. One case on the west bank in section 26, southeast of northeast, where a mass of rocks having the same appearance as the "Chimney Rock," but on a smaller scale, is thought to be an anticline. The topography to the west strengthens this view.

The Chimney rock anticline, or some anticline very close to it, probably explains the structure of Jenkins' spring ridge, a high ridge running a little south of west across the southern row of sections of this township, and is also responsible for the high ridge to the east of the river. Evidences of an anticline appear in 6 S., 25 W., centre of section 27, on the Kirby-Murfreeeboro road.

Structure in Townships 7 and 8 South.

Silver Hill Anticlinal Axis.—In 7 S., 30 W., section 6, southwest quarter, the Cossatot crosses two anticlines, one at Antimony Bluff, and one about three hundred feet further north. In 7 S., 31 W., the topography indicates that one or both of them passes nearly due west, forming the high, flat-topped ridge upon which Silver hill is situated. In 7 S., 32 W., an overturn with a north dip is crossed by Robinson's Fork in section 8, northeast of the northeast. The topography between the two prongs of the Rolling Fork for several miles from their junction is extremely broken, but it shows the strike of the rocks.

Minor Anticlines.—In 7 S., 30 W., section 6, northwest quarter, a single exposure indicating an anticline was found on the Cassatot. In 7 S., 31 W., the Cossatot crosses two anticlines in section 12, one in the northeast of the northeast, and another in the northeast of the southeast. In 7 S., 32 W., the Rolling Fork crosses an anticline in the southwest quarter of section 15, near the mouth of Davis branch. It also appears to cross an overturn with north dips in section 16 east of the centre.

Cave Creek Anticlinal Axis.—In 7 S., 29 W., section 9, near the mouth of Cave creek, the Saline river crosses the Cave creek anticline. Going west it forms an unusually straight valley running a little south of west, down which Cave creek flows. This valley is continuous from the Saline to the Cossatot, but near the Cossatot it is deflected to the south, the axis appearing to be in a sharp ridge in 7 S., 30 W., the northwest quarter of section 20. This ridge ends abruptly in the northeast of section 20. In 7 S., 31 W., it forms the valley of a tributary of Stowe's creek, running through sections 22 and 23. It is here indicated only by the parallel outcrops of thin novaculite and siliceous shale. Through sections 19, 20 and 21 the axis is followed by Bellah creek, forming a broad valley to the Rolling Fork in 7 S., 32 W., section 27. The shales form bottoms on the Rolling Fork.

On the Saline river in 7 S., 29 W., section 16, its structure is that of a simple anticline. To the west, its structure could not be determined, but on Rolling Fork in 7 S., 32 W., low south dips of 10° to 15° point to a monoclinal structure. Fig. 31 shows the composite section exposed along the Rolling Fork.

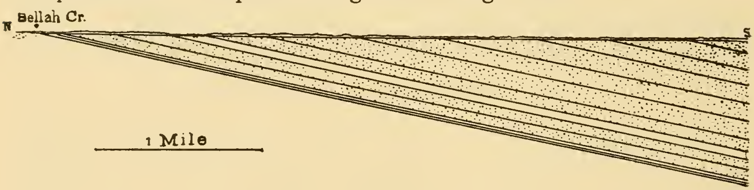


FIG. 31.—Section on Rolling Fork of Little river from Bellah creek southward.

The Blue Ridge Anticline—The topography strongly suggest that the Blue Ridge anticline is a continuation of the "Chimney Rock" axis which runs west through the Jenkins' spring ridge. Jenkins' spring ridge runs a little south of west to Fallen creek, and is cut by two creeks. At Fallen creek it is questionably anticlinal.

Then it runs due west to the New Hope-Centre Point road, where it turns a little north of west to the Muddy Fork. Here the structure is anticlinal. From Muddy Fork to Rock creek it has a south of west direction, and forms a high ridge in 7 S., 28 W.; in the southeast of the southwest of section 2 it forms a high knob. The anticlinal structure shows where the ridge is cut by Holly creek in section 9, northeast quarter, and by Rock creek in section 18, northwest quarter. From Rock creek west the high ridge continues, forming a prominent bluff where it meets the Saline in 7 S., 29 W., section 16.

The Arsenic Cave Anticline.—The Arsenic cave anticline was

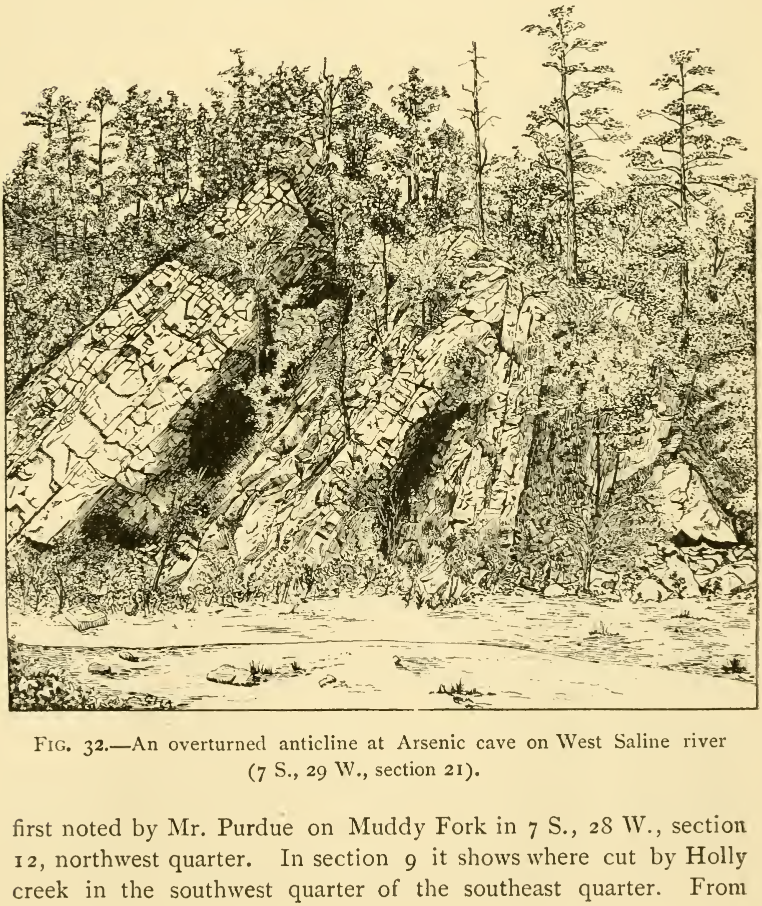


Fig. 32.—An overturned anticline at Arsenic cave on West Saline river (7 S., 29 W., section 21).

first noted by Mr. Purdue on Muddy Fork in 7 S., 28 W., section 12, northwest quarter. In section 9 it shows where cut by Holly creek in the southwest quarter of the southeast quarter. From

Holly creek to the Saline river it forms a high pointed ridge from two hundred to three hundred feet in height, the anticlinal structure showing in several places. At the Saline it is overturned, and where the axis crosses the river in 7 S., 29 W., section 21, northeast of southwest, there is a small cave known as Arsenic cave. Though the overturning does not show quite as plainly at the cave as in several places, this was the only point at which a photograph was obtained of the fold. Fig. 32 is a drawing from a photograph. This axis could not be followed west of the Saline, but it may have some connection with an anticline crossed by the Cossatot in 7 S., 30 W., section 33, in the northwest of the southwest quarter.

Another axis appears to run parallel to the Arsenic cave anticline but one-half mile south of it. This southern axis was found at three places. In 7 S., 20 W., it is crossed by the Muddy Fork in section 12, where it turns to the northeast, and by Holly creek in section 16, northeast quarter. No trace of it could be found on the Saline river. In 7 S., 30 W., it is crossed by the Cossatot in section 33 at the township line.

Other Anticlines.—In townships 7 and 8 S., 25 to 27 W., the structure is much obscured by the over-lying water-worn material and Cretaceous. An anticline is reported by Dr. Branner and Dr. Hay[1] as cut by Holly creek in 7 S., 28 W., section 28, northwest quarter.

Several minor anticlines show in the banks of the Cassatot in 8 S., 30 W., section 4, as shown in the Cassatot section, Pl. ii.

Red Bluff Anticline.—In 7 S., 25 W., a high ridge with a south of west strike makes what is known as Red Bluff where cut by the Little Missouri river in section 6, southwest quarter. The structure appears to be an overturned anticline with south dips. Following this strike in 7 S., 26 W., the dips give an anticline in section 8.

The Wall mountain anticline is shown by the topography to be continued across the northern row of sections of 7 S., 25 W., and south of Cow creek, but its extent to the west is unknown.

The Muddy Fork Overturn.—In 7 S., 25 W., section 10, northeast quarter, Prairie creek crosses what appears to be an overturned anticline with south dip. The topography strengthens this view. A high ridge which starts abruptly in section 12 crosses Prairie creek at this point and runs a little south of west to the Little

[1] *Geol. Surv. of Ark.*, An. Rep. for 1888, Vol. ii, p. 286.

Missouri. At places the top of the ridge is strewn with great monoliths due to the outcropping of a heavy layer of sandstone. In 7 S., 26 W., occur parallel lines of similar monoliths sometimes combining to form a low wall. These were found in the south half of section 16, and north half of section 21, and suggest a similarity of structure or continuity with the overturn exposed on Prairie creek.

In 7 S., 25 W., the Muddy Fork crosses an overturned anticline in section 20, northeast quarter just west of Muddy Fork post-office. The strike places this upon the same axis as the Muddy Fork fold.

Prairie Creek Anticline.—In 7 S., 25 W., Prairie creek crosses an overturn in section 28, northeast quarter. This is one of the few cases where an overturn can be traced as it folds over, then under. This anticline is exposed also in section 30 on the Little Missouri river.

Minor Anticlines.—In 8 S., 25 W., some evidence was found of an anticline crossed by Prairie creek in section 5 near the north section line, and by the Little Missouri in section 6, northern part.

In 7 S., 25 W., section 20, west of the centre, Mr. Hopkins describes the nose of a ridge which, at this point, is very suggestive of an overturn with dips to the south.

In 7 S., 26 W., section 30, a mile north of Nathan, the perpendicular dips indicate the presence of an anticline, and Dr. Hay[1] reports finding an anticline west of this on the Muddy Fork, near the Nathan-Muddy Fork road.

VIII. Theoretical Deductions.

In this chapter we shall discuss briefly some of the problems presented by the structure described in the preceding chapters.

Original Extent of Folded Strata.—A folded layer of rocks does not cover as much space as the same layer spread out, nor would it be a difficult problem to ascertain the difference, if the folds were completely exposed. When, however, it is remembered that we have only an imperfect section along practically a single line (not even a plane), and in addition to this many of the folds are overturned, or so closely squeezed that their upward or downward extension may be a few hundred feet or several thousand feet, and

[1] *Geol. Surv. of Ark.*, An. Rep. for 1888, Vol. ii, p. 284.

also that no correlation is obtainable in most cases, it is readily seen that the problem is a difficult one.

The following method was adopted for obtaining an estimate of the original extent of the folded strata upon the supposition that the folds are not broken, but remain complete until eroded.

North and south sections on the scale of one mile to the inch were made, as for example, down the Cossatot; the structure and dips accurately placed on it, and the folds theoretically completed, and then measured with a scale. The folds were made as short as could be done consistently, and the result may therefore be regarded as conservative. Still this method makes no pretense to accuracy, and the limit of error is certainly not more than twenty-five per cent.

The two best examples gave the following results: The Cossatot section, which is now twenty-four miles long, is estimated to have had an original length of thirty-five miles. The Antoine section, at present twenty miles long, is estimated to have had an original length of thirty-five miles.

If it be assumed that the movement took place from the south, the strata restored to their original horizontal position would spread over the territory now included in all of Clark, Pike, Howard and Sevier counties and the northern part of Nevada, Hempstead and Little River counties.

Had such a method been adopted as that used by Prof. Claypole in determining the original extent of a section across Cumberland county, Pa., there is little doubt that instead of thirty-five miles, we should have had between fifty and one hundred miles, as the sections on Antoine creek and Little Missouri river, with their many overturns, present much the same character of structure.[1]

Without going into a full discussion of the subject, we are led to conclude, that while there has been an apparent shortening of north-south cross-sections from their original position of not less than five or ten miles, and possibly much more, did we know the actual facts of the case, it is probable that such shortening has really been very small, and that the strata occupy nearly the same ground as that in which they were laid down.

Direction of Movement.—In determining the direction of movement three factors have been used: the dip of the axial plane of an anticline, or in the case of an overturn, the direction of over-

[1] Claypole, *American Naturalist*, Vol. xix, No. 3, March, 1885.

throw; the direction of dip of faults parallel to the strike; the general character of folding considered over the whole of the disturbed region.

Thus, in the case of overturns, if they are overthrown to the north, the dips being south on both sides of the axis, it is asserted that movement came from the south. In this region, however, we find overturns overthrown both to the north and south.

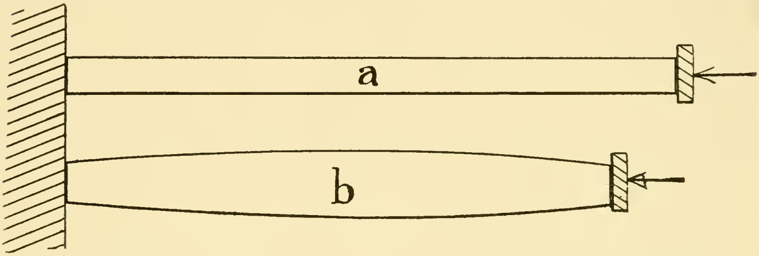
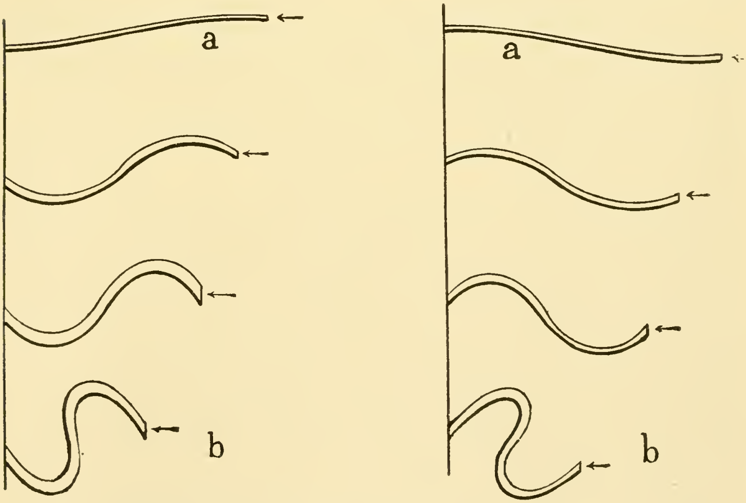


Fig. 33.—Diagram illustrating the effect of horizontal pressure upon a horizontal homogeneous bed.



Figs. 34, 35.—Diagrams showing the effect of original dip upon ultimate structure.

An examination of the subject seems to show that the real determining factor in the direction of overthrow is the initial dip of the strata. Thus a perfectly homogeneous horizontal layer as in Fig. 33*a* subjected to horizontal pressure, evenly applied, will not tend to bend, but to be compressed, as in Fig. 33*b*. If, however, as in Figs. 34*a* and 35*a*, it have a slight initial dip, the horizontal force will, at the point or points of bending, be resolved into two components, one tending to compress and the other to bend. Bending may then take place, but all that is desirable to note here is that, if the bending is carried to overturning, the direction of overthrow is not determined by the direction of movement, but by the direction of dip, as suggested in Figs. 34*b* and 35*b*.[1]

It is true that as a rule this dip will be toward the open sea, and the testimony of other elements show that, in many cases at least, the movement or apparent movement has been from the shore seaward. In such a case the overthrow will be away from the shore, and so there would be a tendency for the rule to hold good that the overthrow is away from the direction of movement. But we are led by the facts observed in this area where there exist overthrows both to the north and south to believe that such reasoning from the direction of overthrow is reasoning in a circle and not to be accepted as trustworthy.

Another element is the direction of dip of faults. This, too, contains the same objection, for, as shown by Daubree,[2] faulting parallel to the strike is governed by the folding, and if, as we are led to suspect, the folding is not entirely governed by the direction of movement, we must consider the faulting as under the same limitations and therefore not a trustworthy factor.

If a section across the Appalachians from southeast to northwest be examined, it will be noticed that the folding, which is intense at the southeast end, gradually becomes more and more gentle until at the northwest end the strata become horizontal.[3] An examination of Fig. 1, shows the same thing; in this case the intensity dies out from south to north. In such cases the evidence seems to be strong, that movement, if any, comes from the direction of greatest or closest folding. This suggests that the movement in our region was from the south.

[1] Dr. E. A. Smith has suggested the same explanation for overthrust and underthrust (*Am. Jour. Sci.*, April, 1893, p. 306), but as Mr. Ashley's paper was written before the publication of that paper his explanation is allowed to stand. —J. C. Branner.

[2] Daubrée, *Géologie Expérimentale*, Paris, 1879, p. 344.

[3] H. D. Rogers, *First Geological Survey of Pennsylvania, 1857.*

Bearing of Certain Features of the Region upon Theories of Mountain Making.—Reference was made in the description of Antoine mountain (p. 273) to the peculiar appearance of the layers where closely bent in the axis of the anticline. They have the appearance of having broken into blocks, and of these blocks having adjusted themselves to their neighbors. The rocks on top of Little Bear mountain present much the same appearance. In neither case do the rocks show noticeable metamorphism, though they are slightly closer grained than most of the layers.

Probably bearing on the same subject are the many cases noted where solid layers are sharply bent into acute angles without showing any sign of fracturing.

It has generally been assumed where such close folding without fracturing occurred that it was due to the confinement put upon it by the enormous vertical pressure of superincumbent beds. It being thought that, though the layer were under shearing stress far beyond its ultimate strength, the great vertical pressure would be sufficient to close every incipient fracture.

Some interesting experiments have been performed by Mr. Bailey Willis of the United States Geological Survey[1] in studying the effect of a horizontal pressure on soft layers under a weight of half a ton of shot. Some of these conditions were produced, and a study made of their action by graphical statics. Very similar results were obtained, but they led to certain questions presenting themselves.

If we assume such a series of layers under a gradually increasing horizontal pressure, the time will come when the bending component of that pressure at some point of initial dip will be sufficient to overcome the various resistances and forces opposing it, and the layer will begin to bend. If, when the layer has bent slightly, we make another examination of the components, forces and resistances involved, we shall find that the slight bending has given the bending component of the original horizontal pressure an advantage, and it has increased at the expense of the compressing component. On the other hand the resistances and forces opposing it remain about the same, hence its movement would be accelerated, and soon the bending would go forward with a rush until finally the horizontal pressure is transmitted across the fold instead of

[1] Bailey Willis, *Transactions American Institute of Mining Engineers*, June, 1892, xxi, 551–566; Thirteenth An. Rep. *U. S. Geol. Surv.*

along it. If the force not used up by the first fold were great enough other similar folds might be made.

Figs. 33 to 35 outline the action, only the main or combined forces or resistances being given in the figures. The conditions assumed are similar to those of Mr. Willis' (L) model (not given in the paper referred to). In this case the forces are only considered in reference to the main heavy layer, the others being assumed to be soft shales with little power of transmitting pressure. The question then arises, How can bending take place unless the bending component be as great as assumed at the moment when bending begins? A study of the rocks of Antoine mountain and elsewhere has led to this suggestion. May it not be accomplished by a much smaller force by introducing the factors of great length of time in connection with viscosity of solids?

It is now generally held that mountain making is a process of thousands of years, the movement being, as a rule, so slow as to be imperceptible, and yet we still cling to the idea that the forces and resistances involved are such as would be involved in rapid laboratory experiments. Thus a bar of stone is placed in the machine for testing the bending strength, and the result obtained is used in the study of mountain making.

Experiments have shown that solids under pressure below their ultimate strength but above their elastic limit will flow in the same way as will a plastic substance like putty. They have also shown that the elastic limit becomes lower when more time is allowed the pressure in which to act; and examples have been found of marble slabs, which have lain many years, bending[1] under their own weight without fractures, though when first placed in position they would not have bent under several times that weight, and would probably have broken before bending perceptibly. In Mr. Willis' experiments it may be that the plasticity of the materials made up for the shortness of time in which movement took place.

We are led to the conclusion that the folding may be due in part to flow of the cold solid rock under a comparatively small pressure continued over a great length of time.

[1] Winslow, *Am. Jour. of Sci.*, iii, Vol. xliii, p. 133. Ashley, *Proc. Cal. Acad. of Sci., 1893*, p. 319. See also Gibbs, *Am. Nat.*, Vol. iv, Jan., 1871, No. 11, Salem, Mass., p. 695.

IX. Post-Carboniferous History.

Period from Carboniferous to Cretaceous.

If in the sections of Pl. II the strata be restored above the surface, it will be seen that a great amount of erosion has taken place. The fact that the eroded upturned edges of the Carboniferous rocks have the Cretaceous rocks resting unconformably upon them is sufficient evidence that this erosion took place between Carboniferous and Cretaceous times.

What was the extent and character of this erosion? Mention has already been made of the peculiar character of the topography along the southern border of the area. Thus, if we start from the level Cretaceous country and travel north over the Paleozoic, selecting a road which avoids the immediate neighborhood of the larger streams, as for example, the county roads to Amity from Arkadelphia, from Hollywood, from Clear creek, from Murfreesboro, the Old Drove road north from Nathan, the old Stewart road from Atwood toward Galena and others, we cannot help noting as we leave the Cretaceous border and proceed northward that the almost level character of the country continues without break, except where small streams have made small valleys. The elevation increases from two or three to eight or ten miles when east and west valleys abruptly end the level surface. The lateral extent of this flat country is governed by the encroachments of the nearest streams on either side. In some cases where the tributaries of the south-flowing streams run east and west the level topography reaches out from the main divides and forms flat, minor east and west divides, which extend almost or quite to the south-flowing streams and form bluffs on those streams from 200 to 300 feet high. In short, the whole topography suggests an original surface nearly level, but rising gradually to the north and west over all the southern portion of the region. Into this streams have later cut their channels, in some cases to a depth of 200 to 300 feet, and in many cases have eroded the surface to such an extent that all vestiges of its original character are lost. The present northern boundary of this flat country is exceedingly irregular, but in a general way is indicated by the northward extent of the Post-Tertiary drift upon the roads mentioned above, as shown on the maps. How far north the Cretaceous extended is not known. A quarter of a mile west of Star-of-the-West a single piece of Trinity limestone was found, and it is said that formerly such limestone was plentiful at that locality. In 7 S., 32 W., or 33 W., near the north township line limestone full of fossils is reported as occurring plentifully on a ridge west of Cross creek. This could not be verified. These suggest the possibility of the Cretaceous deposits having been originally laid down all over this region. This view is strengthened by the character of the Cretaceous deposits, limestones, chalks, etc., implying at least fairly deep waters over the region.

Cretaceous and Tertiary Periods.

During the Cretaceous and Tertiary periods the southern part of Arkansas was the theatre of several gentle oscillations of level which find record in the varying deposits bordering on the south.

For the details of this history the reader is referred to the Survey's reports on the Mesozoic and Tertiary.[1]

We must, however, note the land epochs, as it was probably during one or all of these land epochs that the present drainage systems of our region were inaugurated and fixed. Two have been noted during the Cretaceous and another follows the Tertiary subsidence.

Frequent references have been made to the way the main drainage streams cut across the structure, being influenced by the strike of the folds only to a minor degree. In the novaculite area this feature of the larger streams is still more marked, the Little Missouri and Cossatot being good examples. In some cases these streams cut across high ridges, when, by a short east or west offset, they could have run around them.

Remembering that the Cretaceous strata were originally much thicker than they now are, if we replace these deposits, which have a gentle south dip, they would doubtless extend well northward toward or to the Ouachita mountains. Supposing now the movement of elevation takes place. These new strata would gradually become a land surface. Streams would start from the point of highest elevation and run seaward. If a map of western Arkansas and eastern Indian Territory be examined, it will be found that there is such a centre from which drainage flows in all directions. This centre is in the neighborhood of the Rich mountains, at the

[1] *Geol. Surv. of Ark.*, Rep. for 1888, Vol. ii, p. 182; Rep. for 1892, Vol. ii.

western end of the Arkansas base line. To the north runs the Poteau river, to the northeast the Fourche la Feve, to the east the Ouachita, to the southeast the Caddo and Little Missouri, to the south the West Saline, Cossatot and Rolling Fork, to the southwest the Mountain Fork of the Little river, and to the west the Black Fork of the Kimishi river.

We may then assume that that region was the centre of elevation for the land period that gave rise to the present drainage.

We can readily imagine a condition of things, such as at present exists in the Cretaceous region, having previously existed over the whole area. The creeks and rivers following the general slope of the Cretaceous strata, entirely unaffected by the buried Paleozoic sandstones. Then as they sink their channels until the Paleozoic strata are reached, they find it easier to continue sinking their beds than to force their banks and make new channels conformable with the softer rocks.

If next, we suppose that, due to shore conditions, the thickness of the beds diminished to the north, we can understand how erosion would first expose the Paleozoic strata at the north and the line of contact would gradually move southward until it reached its present position.

As erosion began to cut deeply into the Paleozoic strata, the minor streams yielded to the influence of structure and became in time structural streams, and the larger streams, though maintaining their first courses in a general way, became conformable to the structure in minor details of their courses.

In which of the land epochs the present drainage originated and became fixed we do not know. It must be remembered that these land periods each produced a nonconformity in the Cretaceous and Tertiary rocks, so that it is not impossible that all the effects of erosion during one land epoch may have been erased in the next subsidence, new beds being laid down and the next land epoch beginning a new system of drainage. However this may have been, the evidence seems to show, that, at the end of the land period following the Tertiary, the topography of most of our area was much as it is to-day, therefore it will be discussed at this point.

Drainage of the Area.—The direction of the main streams would be represented diagrammatically by drawing radiants from the centre of drainage at the western end of the Arkansas base line.

To the northeast of the Caddo are four smaller creeks, Blakely creek, Prairie creek, Bayou Delile, DeRoche creek. Between the Caddo and the Little Missouri are Terre Noir creek and Antoine creek. The still smaller creeks are shown on the maps. As a rule, the tributaries run at right angles to the main streams. Thus, the Caddo runs nearly east, its tributaries nearly all run south, and this same relation can be traced with but few exceptions to the Cossatot, which runs south, but has east and west tributaries.

Going from east to west the general elevation increases more rapidly on the north edge of the maps than on the southern; consequently the difference of elevation between points on the north and south edges of the maps is greater in the western part than in the eastern.

The effect of this is quite marked, both upon the character of the streams and upon the topography; this is still further intensified by the direction of the streams in the eastern part, giving them the advantage of the longest side of the slope. Thus the Caddo and other streams in that region may be characterized as a succession of long, deep pools connected by short rapids having only a few inches, fall. Further west the Cossatot and Rolling Fork are, for much of their courses, shallow, rapid streams with but few stretches of quiet water.

Comparatively speaking all the streams are rapid. The more western streams probably averages between fifteen and twenty-five feet fall to the mile; the Caddo has a fall of seven or eight feet to the mile.

In the same way the topography changes from east to west. In the east it consists of broad valleys with many bottoms along the streams. In the west the valleys are narrow, deep and steep-sided. In the Cretaceous area the smaller streams are mostly surface streams not having cut channels of any great depth. This, to a large extent, is also true of the smaller streams of the Caddo valley, though, where their courses compel them to cut across ridges, they become more rapid and have abrupt banks. In the western part, where the tributaries as a rule follow structural lines, they sink their beds rapidly in the shaly strata, producing deep, narrow ravines, and where these are quite numerous, the topography becomes exceedingly broken.

The Overwash Gravels.

Spread over both the Cretaceous and Carboniferous areas is an overwash of gravels, sands and occasionally a little yellow clay. These deposits are of great thickness along the northern edges of the Cretaceous rocks, while, as a rule, they are but thin on the Carboniferous beds. These gravels and cobbles are well-rounded or flattened fragments of novaculite of almost every color, from black to white, yellow being most common, followed by gray, red, brown and a mottling of these. Sandstone boulders are also mingled with the novaculite pebbles. These water-worn boulders vary from the size of one's fist down, but occasionally they are as large as one's head. Sometimes a hillside is covered with the novaculite boulders bleached so white that they resemble snow.

Sometimes the gravels are cemented together by iron, forming a conglomerate. Sometimes beds of considerable thickness are thus cemented, as, for example, near Wolf Creek P. O., on Wolf creek, Pike county.

The character of the overwash gravels is well illustrated in a fresh cut near the depot at Arkadelphia on the side of the road running north to the business part of the town.

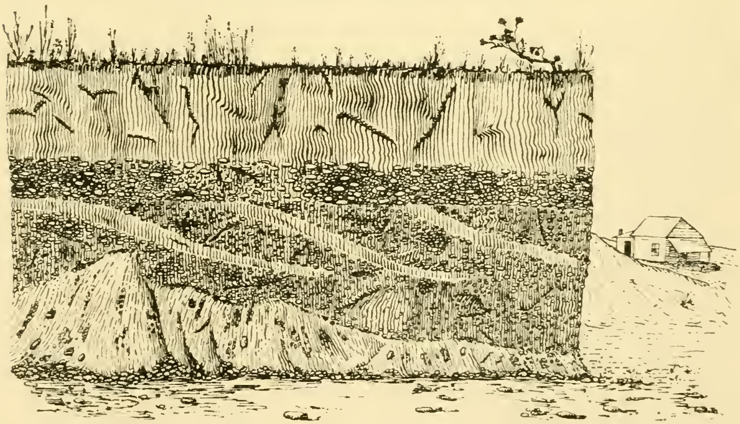


FIG. 36.—Section of gravel bed near the railway station at Arkadelphia.

	FEET.
(*a*) A layer of sandy clay, red, mottled with gray, at the bottom all gray, at the top all red........	$3\frac{1}{2}$
(*b*) A layer of yellowish red gravel from very fine to the size of a hen's egg or larger.............	$1\frac{1}{2}$

	FEET.
(*c*, *d*) A bed of fine gravel (*c*) into which there run thin layers (*d*) of sandy clay without gravel, the fine gravel being the size of a pigeon's egg and smaller	4
(*e*) Talus to level of road	2–4

As the cut was but a few days old when noticed, it seems highly probable that the red color at the top of (*a*) is due to the oxidation of the iron, the color where freshly exposed being gray; the gradation from the pure gray at the bottom to the deep red at the top exhibits very nicely the process of oxidation.

The relation of the bed of firm sand to the other beds of that period is shown on Antoine creek in 8 S., 23 W. In section 14 it forms a ten-foot bluff for a thousand feet, overlying two or three feet of gravel.

At the Antoine crossing of the military road to Fort Towsen and

FIG. 37.—Section at the crossing of the Fort Towson road and Antoine creek (8 S., 23 W., section 24).

above, section 24, it appears again, Fig. 37 being a cross section at that point. We have:

	FEET.
(*a*) Bed of gravel dipping east or southeast and lying on a soft, friable sandstone dipping 45° south	8
(*b*) Bed of firm sand with same dip..............	8
(*c*) Outcrop on east bank of soft yellow or brown sandstone dipping 70° south, 25° west..........	3–5
(*d*) Thin bed of novaculite gravel................	2
(*e*) Bed of very firm sand	8–10
(*f*) Gravel	?

The age of the sand in this case depends somewhat on the age of the uppermost gravel, which is evidently the younger. But the gravel on top may be a very recent deposit made by the creek.

The beds of gravel attain no great thickness in the Paleozoic region. In the northern part they usually consist of scattered boulders, all the finer material having been removed. At the northern edge of the area, over which it still exists in an undisturbed condition, it is comparatively thin. But going southward it gradually increases until, at Centre Point, there is an exposure of seventy-five feet of it in a bluff. Mr. Hill estimates that a mile south of Centre Point it has a thickness of two hundred feet.[1]

The undisturbed gravel deposits occupy an irregular area on the west side of the Ouachita river for a mile or two from the river, and from a mile south of Social Hill to Rockport. They occupy all of 6 S., 19 W., except the northwest corner. Passing westward the northern escarpment follows the Chalybeate mountain in an irregular line through 20 west, swinging south in ranges 21 and 22 west, it crosses range 23 west about in the centre of 7 south. It reaches this far north in each range to the west until the West Saline has been crossed, west of which gravel was only noted in spots.

North of this line gravel was found in nearly every township east of the West Saline river, occupying areas from five or six square miles down to a few acres.

Generally these consist of scattered boulders of water-worn novaculite; some show a little fine material as though they represented fragments of undisturbed deposits.

All the beds of the creeks which rise among the novaculite ridges contain more or less water-worn novaculite gravel, but in those in the northeast part of the region this gravel sometimes constitutes the valley bottom, the creek cutting down through it, and in places exposing a thickness as high as six feet. Prairie Bayou, Big Hill and Valley Fork of Point Cedar creek are examples of this kind. In the centre of a large curve in the Caddo in 5 S., 23 W., section 22, northwest quarter, the deposit of gravel reaches a depth of thirty feet. It is not probable that these are original undisturbed deposits, but remains of a subsequent deposit, made when erosion carried the gravel from the higher ground and filled the valleys faster than the streams could carry it off.

In 5 S., 28 W., section 24, Mr. Purdue found two elliptical knobs or mounds one hundred feet or more long and fifty feet high, which, to all appearances, seemed to be made up entirely of novaculite water-worn gravel. One of them is known as Round mountain.

Distribution in Other Regions.—Without asserting an exact cor-

[1] *Geol. Surv. of Ark.*, Ann. Rep. for 1888, Vol. ii, p. 40.

relation, it may be said that there occur deposits of approximately the same age and of the same character in Alabama, Mississippi, Texas and Indian Territory.[1]

Age of the Gravel.—No fossils have been found in these gravels, so that the only determination of their age possible is by their stratigraphic position. They lie unconformably on the Paleozoic and Cretaceous. Similar gravels overlie the Tertiary, and are therefore of more recent origin, and on that account the age of the gravels is given as Post-Tertiary.[2]

X. Economic Geology.

Minerals and Stones.

Minerals.—Many have been led by the disturbed condition of the layers all over this area to think that mineral of some kind must exist here in quantity. Much prospecting has been done and many thousands of dollars expended in sinking shafts and prospect holes, but all without results, except in a small belt in the northern part of Sevier county. For convenience it may be well to consider first this belt which is known as the antimony district.

The Antimony District.

The ores found in this district have been discussed in the Survey's report on Gold and Silver, to which the reader is referred.[3] As Prof. Comstock misinterpreted the structure in this district, it may be well to state that more fully.

Extent of the Antimony District.—As defined by localities in which ore has has been found, the antimony district lies entirely in

[1] Tuomey, *Second Biennial Report on Geology of Alabama, 1858*, p. 144. Hilgard, *Report on the Geology and Agriculture of the State of Mississippi*, 1860, pp. 3–46. Hilgard, *Amer. Jour. of Sci.*, May, 1866. *Geol. Surv. of Ark.*, Rep. for 1888, Vol. ii, pp. 43–47.

[2] Mr. Ashley's paper was written before the publication of the report on the Tertiary of Arkansas by Professor Harris. The latter author has, in my opinion, solved the problem of the age of these gravels. He regards them as shore deposits "laid down under similar conditions, though by no means in the same geological epoch," and he thinks that their "rearrangement presumably took place before the close of the epoch represented by the underlying stratified beds." See *An. Rep. Geol. Surv. Ark.* for 1892, Vol. ii, 7–9. *The Tertiary Geology of Southern Arkansas.* By Gilbert D. Harris.—*J. C. Branner.*

[3] *Geol. Surv. of Ark.*, Rep. for 1888, Vol. i, p. 136, *et seq.* See also Wait, *Trans. of Am. Inst. of Mining Eng.*, Vol. viii, 1879–1880, pp. 42–52.

township 7 S., ranges 29–32 W. inclusive; in 7 S., 29 W., however, the Busby mine is the only place where ore was found. Thus it may be said to be about twenty-four miles long by four miles wide, and has a very slight south of west trend, occupying the northern part of the eastern townships and the central part of the western.

Prospectors report finding traces of stibnite north of this region, but as in no case has it seemed to warrant the expenditure of time or money in exploitation, the district may be considered as fully comprehended in the limits given.

Structure of the District.—The structure in this district is obscure, the topography is broken, and outcrops of bedded rock are scarce. Such structure as was obtained was derived partly from exposures in shafts and prospect holes. As shown in the Cossatot section of Pl. ii, there appear to be about half a dozen anticlines in the district, though only half that number could be found on the Rolling Fork and on the West Saline. As shown in the section, the anticlines are closely folded, giving many high dips. No evidence of faults, which play such an important part in Prof. Comstock's interpretation of the structure, was found, but this must be considered as having only a negative bearing, as faults doubtless do exist all through this region. The Silver Hill anticline or anticlines have a strike of less than 5° S. of W. The Cave creek anticlinal axis has a strike of from 5°–10° S. of W.

The rocks in the districts are the same as all over the region—shales, shaly sandstones and sandstones. The thin bedded novaculite occurs in such a way as to suggest that, if the strata under it are Silurian, then the Silurian is extensively exposed in this belt, if indeed it be not the predominating formation.

Character and Occurrence of Ore Deposits.—The ore deposits of this district are in the form of bedded veins. While they usually follow the bedding in strike and dip, they frequently run at small angles to the dip, and it is claimed that in a very few cases small deposits are found crossing the bedding, but none were seen. They occur mostly in shale, but though a contrary claim was made, they were also found in sandstones at several places. The veinstone is quartz and varies from a thin layer, in which the quartz simply forms a matrix for fragments of the country rock, to veins four feet thick and very pure. The ore occurs as lenticular masses in the quartz from two inches to twenty-two inches thick, and occasionally of considerable extent, as one mass is said to have yielded over seventy-five tons of clean stibnite. This quartz veinstone is frequently exposed at the surface as a low wall, and in one case in 7 S., 32 W., sections 8 and 9, this is easily traceable for nearly a mile. The veins are of such a character that there is always much uncertainty about the occurrence of paying ore. A shaft at the Valley mines has been sunk 230 feet and still shows good ore, while others have run out in a short distance below the surface.

Along the Rolling Fork exploration revealed twelve ore-bearing veins within two miles. In the region just south of Antimony City it is claimed that five leads or veins have been found.

Similar quartz veins are common north of this tract in townships 5 and 6 S., but no ore has been reported from them.

Ores.—The main ore and the only ore as yet found in paying quantities is stibnite. Silver and lead are found in small quantities. In still smaller quantities or occurring only as traces were found sphalerite, cervantite, jamesonite, pyrite, chalcopyrite, arsenopyrite, tetrahedrite, and a few others.

Ores Outside of the Antimony District.—There are a few places north of the antimony district where the general appearance of quartz veins suggests a similarity of conditions to those found in the antimony district. But, with these exceptions, the remainder of this Paleozoic area does not give evidence of containing ore of any kind in any quantity; in fact, in view of the careful prospecting that has been done and the negative results obtained, strengthened by a study of the geology of the region and the character of the rocks, the evidence seems to be against the existence of pay ore in the region.

Silver.—During the silver excitement a few years ago all the northern edge of this territory in the eastern part was thought to be included in the silver district, and a large portion of it was taken up in claims. Much prospecting was done and many shafts were sunk, but no one reports finding any silver, or getting an analysis that gave more than a trace of it.

Very recently a prospect hole has been started just north of Caney Fork P. O., based upon the finding of two or three small pieces of silver at that point. One of the pieces seemed to be almost pure silver, about the weight of a dollar. It had evidently been run out and worn smooth; it was certainly not as it came from the earth, though still in the condition in which it was found. The finding of Indian "tools and hammers" in the same locality might explain the presence of the silver. For the tools are undoubtedly Indian implements, such as are found all over the region, and instead of suggesting an old mine, suggest a camping place. The silver belonged to the Indians and was brought from nobody knows where.

Traditions of rich silver mines are plentiful, but they always go so far back and contain so many improbable factors that they may be dismissed as of no value except to entertain the traveler.

Lead.—Lead is often reported as having been found in the region. The localities given, though not definitely known, were all in the Caddo valley. It is possible that a little lead may occasionally be found, though the geology makes it appear improbable that it should ever be found in any quantity.

Manganese.—The northern portion of the region borders on the manganese district of southwestern Arkansas, and in a few instances traces of manganese were found on anticlines well in the centre of the region.

The ore, in quanties sufficient to color the joints in the sandstone, is quite common. Occasionally it occurs in small masses as a conglomerate or mixed with iron. The original bed, or more properly plane of occurrence, is a bed at the top of the novaculite series. It partakes of the same folding as the novaculite, and will be found, not as a level bed, but as an outcropping edge of the layer parallel to the neighboring novaculite layer, and, except as modified by the topography, usually running along the side hill of a novaculite anticline.

The ore occurs in pockets difficult to mine and generally in very small quantities. Those interested in the manganese of this part of the State should consult the Survey's report on manganese.[1]

Iron.—Iron as a commercial ore does not exist in this territory. A few loose pieces of impure bog iron ore occur especially around the chalybeate springs, where the sandstone is highly impregnated with iron. With these exceptions iron exists here only as the coloring and cementing material of the red and brown sandstones and conglomerates. Iron is sometimes found in the same bed as the manganese, but as such deposits are properly north of the area in every case, the reader is referred to the Survey's report on iron.[2]

[1] *Geol. Surv.of Ark.*, An. Rep. for 1890, Vol. i.

[2] *Geol. Surv. of Ark.*, An. Rep. for 1892, Vol. i.

Salt, Soda.—Though indefinite reports of salt having been found in the region were frequently heard, all those that could be traced out proved to have come from wells or springs in the Cretaceous border on the south.

Soda is said to exist as an efflorescence in a cave on the Little Missouri in the northern part of 7 S., 25 or 26 W.

Summary of Mineral Prospect.—As far as shown by exploration and exploitation up to the present time, paying ore has been found only in a small belt in northern Sevier county, and but one ore, stibnite, has been found in that district in paying quantities ; though silver and lead ores have been found in small quantities. In speaking of stibnite as a paying ore, it is meant that it might be remunerative under more favorable conditions of transportation, smelting, etc. In the present state of things no reliable judgment could be given on the future of the antimony interest in this region. Whether the ores exist in quantity, or whether the richest deposits have already been exhausted, are questions that cannot be answered without a more thorough examination of the detailed geology of the antimony district than the State Survey could undertake. The output in 1890 was 54,188 pounds, but in August, 1892, none of the mines were being worked.

Commercial Stone.

Building Stone.—It is possible that the ferruginous varieties of sandstones may prove of value as building stones: they dress easily and acquire a firm surface afterward, but on account of their brown color it is hardly probable that such stone, even though its wearing qualities be good, will ever be very popular.

There occasionally occurs locally a form of the sandstone, both pleasing in appearance, and, judging from weathered fragments, of good wearing quality. It is a slightly metamorphosed white or light gray sandstone, and varies from a sandstone hardly altered to an almost pure quartzite, the harder varieties, however, being too hard to work easily and therefore of less value. A typical outcrop occurs on Winfield creek, just below the junction of the east fork in 7 S., 21 W., section 10, northwest quarter. An outcrop on Antoine mountain in 6 S., 23 W., section 19, and one reported by Mr. Hopkins on Prairie creek in 7 S., 25 W., east of the centre of section 10, might be mentioned, and numerous other small outcrops were noted.

Considering the great extent of country to the south and east without building stone of any kind, it was hoped that stone of value would be found in this, the nearest of the rock-covered mountain country. At present rock is used here only for lining chimneys, the ferruginous sandstone and slabs of laminated sandstone being used for the purpose.

Millstone Grit.—Grits have been noted and described in preceding chapters. Rock of this kind is fairly abundant, but it is only here and there that it is firm enough to be used as millstones. Quite a number of these have been cut from it, several having come from the outcrop on top of the Chalybeate mountain just west of the Caddo river in 6 S., 20 W., section 14.

It is claimed by some that the meal ground with these stones is always gritty, and whether for that or some other reason, there are, as far as could be learned, none of the millstones running at present.

Grindstones.—A few attempts have been made to cut grindstones from the sandstone. None of these were seen, however, nor could it be learned just what kind of sandstone was used. Some stones were obtained from the part of the Chalybeate mountain east of the Caddo, whence that portion of the mountain took the name of Grindstone ridge. Similarly Grindstone creek, a tributary of Antoine creek in 8 S., 23 W., section 15, took its name from the occurrence there of a gritty sandstone from which grindstones have been made.

Slates.—The only places where slates give promise of any value is along the Rolling Fork in 6 S., 32 W.; and west of there near the State line, Owen reports good slate.[1] But it is doubtful if these have sufficient value to pay for working.

XI. Agriculture, etc.

Soils.

The soils of the region are of three kinds:

1. The red and brown soils of the overwash gravels.

2. The residuary soils formed by the decomposition of rocks in place.

3. The alluvial or river bottoms soils. These will be taken up in this order.

The Overwash Soils.—The overwash soils consist of gravel and

[1] Owen, Second *Geol. Surv. of Ark.*, p. 112.

sands with some clay. As shown by analysis, they are lacking in lime, and, over much of the region, the proportion of gravel to sand is so large as to make the land of little value with present modes of farming.

However, when the value of fertilizers becomes recognized, it is probable that this section, with its level yet well-drained areas, will form some of the most desirable agricultural land in the region.

At present a great forest of pine with some hard woods covers nearly the whole exposure of the overwash ; there are but few farms and habitations on it at present.

Residuary Soils.—Residuary soils are those formed by the decomposition of the underlying rocks, and, as in this region these rocks are mostly sandstones, we have little else than sands with some clayey sands in the valleys.

Almost universally these soils have been enriched by the decaying leaves of the all-prevailing forest. This gives, when first cleared, considerable fertility, but as fertilizers are for the most part wholly unknown, or unthought of, this richness lasts but a few years. There is no doubt but that this soil, primarily rich, may, by proper care and the use of fertilizers, be made not only to maintain indefinitely its fertility, but even to become more productive with time. Proof of this exists in the very rare cases where some one does use fertilizers, with the result of every year raising twice as much to the acre as any of his neighbors, and each year leaving the land in better condition than the year before.

Alluvial Soils.—The alluvial soils form the bottom land along all the streams of any size. They are the cream of the agricultural lands. The reason for this is that they not only combine all the elements found in the other soils, but the rich vegetable mould, which in the residuary soils forms a layer on top, is here disseminated from top to bottom, so that they retain their fertility a long time. The idea so generally held that they will retain their fertility indefinitely is of course not correct.

The bottom lands are generally flooded lands upon which the river has for long periods deposited its load of silt and mud, until, having changed its course or deepened its channel, the land is left suitable for use. They are lacking in lime, as no lime is touched by the depositing streams. A few of them are still subject to overflow in highest water, which, to some extent, renews their fertility.

Amelioration of Soils.—Fortunately the work of Geological Survey has shown that in the Cretaceous region there are extensive deposits of gypsum, marls and chalks containing the elements needed by these sandy soils.[1]

The present methods of farming require that new clearings be frequently made and new fences built. The same amount of labor, expended in fertilizing, would increase crops, and increase the value of land.

Timber.

Timber is at present the greatest latent source of wealth, and in consequence of the roughness of much of the region it will always play a considerable part in the sources of income. In the southern half of the region, where the Pleistocene gravel occurs, the timber is mostly pine; in some districts it is exclusively so, except in the creek bottoms. In the rest of the region both pine and hard wood are found, the latter being the more abundant and consisting largely of oaks.

This mountain timber is said not to be as even-grained as that growing in the bottoms, but has less sap and greater durability.

Of the oaks, the white oak is most abundant; red oak, post oak and others occur less frequently. The short-leafed pine is probably more abundant than any other single species of tree, especially over the gravel-covered area of the southeast, where magnificent forests of it are common. Sweet and black gum are plentiful in the southern and eastern part, and in the same part of the area is much holly. Cedar has been plentiful along the Cossatot and Rolling Fork; ash, hickory and many other valuable woods are well scattered over the region. As before stated, the whole area is one vast forest except for the few clearings made for cultivation.

At present, from lack of transportation facilities,[2] these forests have only a nominal value. But the timber near the railroad is being cut so rapidly that already the lumbermen are beginning to reach into this area. For this reason timber here has a prospective value sufficient to make it worthy of careful saving. At present it is treated in a most wasteful manner.

Relation of Geology to Culture.—The relation existing between the portions of a region under cultivation to the geology of the region is seldom more interestingly shown than in this area. The

[1] *Geol. Surv. of Ark.*, Rep. for 1888, Vol. ii, Chaps. xxii–xxvii.

[2] This report was written before the construction of the Kansas City, Pittsburg and Gulf Railway through the western part of Arkansas.—*J. C. Branner.*

two factors in the geology are the shales and shaly sandstones and the structure which governs the exposures of these shaly layers. The shaly layers for a number of reasons being favorable for cultivation, the structure that brings the shales to the surface brings culture.

If on a map of the region all the land under cultivation were shaded, it would be found that instead of being irregularly scattered, the shaded portions would run in belts, some narrow, others broad, while between them in several places would be belts of almost entirely unshaded territory, sometimes several miles broad, and from twenty-five to seventy-five miles long.

These broad belts of unsettled territory are frequently nearly level, or but slightly rolling, but they are mostly uplands. The one feature which distinguishes them is that they are outcrops of the great sandstone beds which form the upper portion of the columnar section of the Paleozoic strata of this area.

The strips of well-populated country run east and west, following the structure, and as they are almost exclusively confined to the valleys, the valley features of the topography will be briefly reviewed.

On the eastern sheet the largest valley is the Caddo valley, contained mostly in township 5 S., and running from the Ouachita river to the divide between the head waters of Antoine creek and the Little Missouri river. It is enclosed on the north by the Trap mountains and Brooks mountain, and on the south by the Chalybeate mountain and its continuation westward. Its main stream is the Caddo, and in it is contained the best farming land in the area, as well as the largest villages.

Notice the arrangement of the post-offices in this valley. On the Prairie Bayou anticline are Social Hill and Saunder's. South of them lie, in a line, Maddry, DeRoche, Bismarck, Valley, Point Cedar and Big Elm, not all on the same anticline, but on the major anticline.

At its western end the Caddo valley is broken into four minor valleys by three ridges: Rock Creek valley just north of Pine mountain; Antoine valley between Pine mountain and Big Bear mountain; Woodall valley between Big Bear mountain and Antoine mountain, and Walden valley between Antoine mountain and Straight and Wall mountains. The valleys in each case take their names from their main streams and are all well settled.

South of the Chalybeate mountain is a well-marked valley, known as the Chalybeate valley. This is wedge-shaped, with the point at Antoine creek in 6 S., 23 W., section 34, widening out to the east between the Chalybeate mountain and the high ridges in the north tier of sections of 7 S. At the eastern end it opens out and merges into the flat country in that direction. Its principal streams are those forming the head waters of the Terre Noir.

Caney Folk valley is an east and west valley a little further south. Starting from the head of Caney Fork of Antoine creek, 7 S., 24 W., section 7, it runs east, becoming lost in the level country north of Hollywood. From west to east it is bounded on the north by Wall mountain, Straight mountain and the ridges south of the Chalybeate valley, and on the south by the high east and west ridges which form the north edge of the old base level in the centre of 7 S., 21–24 W. It is followed all the way by the Arkadelphia-Murfreesboro road. In the area covered by the western sheet no such marked valleys occur. There are, however, a few belts, sometimes of indefinite limits and extent. They generally represent major anticlines, on which may be several minor anticlines. In these cases the folding as a whole is such that shales have been quite freely exposed, and it is along these belts that the land has been taken up and in which most of the settlements occur, so much so that, if the land under cultivation were indicated on the map, it would quite fairly outline these structural features as previously suggested.

Such a belt usually occurs just south of the novaculite ridges, as between Warm Spring and Brooks mountains on the north and Pine mountain on the south. It is indicated by the post-offices: Rock Creek, Wilson, Lodi, Langley, Port Logan and Ethridge. This is but an extension of the Rock Creek valley above mentioned.

The Antoine valley extension of the Caddo valley runs north of the Bear mountains and the Pine mountain in 6 S. To the north it extends toward the Pine mountain south of Rock creek. In the western part of 6 S., 27 W., the western extension of this valley is joined by a continuation of Woodall valley and then runs a little south of west. It is bordered on the north by White Oak creek and Silver Hill anticlinal axes, and on the south by Blue Ridge anticlinal axis and Cave Creek anticlinal axis. This belt follows the structure and shows the same lithological characters over the whole distance; in fact the same as those along the same strike to the Ouachita river. Kirby, Gentry, Star-of-the-West, New Hope and other settlements lie through the centre of this valley.

To the north of this belt the Brushy Branch anticlinal axis exposes shales and produces a low and well-inhabited area.

The Galena and Little Possum creek anticlines in like manner are not productive of strong topographic features and are well under cultivation.

Water Power.—Most of the larger streams carry some water all the year round. In the eastern part, however, the larger streams present but few opportunities for obtaining water power ; though in a few places, as on the Caddo, where the stream makes a long and close bend or horseshoe, power might be obtained by carrying water over the neck at some narrow place.

In the western part the streams have more fall and opportunities for obtaining power are frequent. Many small mills and cotton gins exist there already. In many places the topography is such as to render the building of dams of twenty or thirty feet height, a comparatively simple problem. There are no falls of more than a few feet, unless the Falls of the Cossatot be counted such (the stream here drops between twenty and thirty feet by a series of small jumps in a space of less than a quarter of a mile), but in many places where ridges are cut through, the channel is narrow, giving facilities for building dams, while the fall is so rapid that but little land would be flooded by back water.

With the utilization of such cheap power there is no reason why cotton and other products, instead of going south to the railroads and then north to the mills, should not here be converted into cloth and other manufactured products.

Mineral Springs.—Several mineral springs have become quite well and favorably known as summer watering places for people from south Arkansas, Louisiana and Texas. The best known of these are :

Mineral Springs in 8 S., 22 W., section 18.

Jenkins' Springs in 6 S., 26 W., section 34.

Baker's Springs in 5 S., 30 W., section 14.

Gillam Springs in 4 S., 30 W., section 22.

Tyra Springs in 5 S., 32 W., section 2.

Bog Springs in 5 S., 32 W., section 10.

All of these springs are pleasantly located. At the present time the Mineral Springs in Clark county and Jenkins' Springs are the only ones much resorted to. The former is described in the Survey's report on mineral waters.[1]

Mineral Springs, Clark county, are two miles northeast of Antoine post-office, a quarter of a mile south of the military road, immediately on the Amity-Okolona road. Seven springs issue near each other and one larger spring a short distance away. These springs are well tiled and the large one has a cover. The water issues from a dark-colored, sandy deposit, with streaks of black shale or clay, all of which are probably of Cretaceous age. These beds dip to the south at an angle of 45°. The place is used as a local summer resort and camping place. An open Methodist Chapel, a dozen or more summer cottages and frames for a number of tents have been built at this locality.

The others have all been largely resorted to. For the past few years it has been claimed that there have been as many as five hundred people spending more or less of the summer at Baker's Springs. The principal constituents of these springs is given by Owen[2] as follows:

Analysis of Baker's Sulphur Spring Water.

"Carbonate of alkali, which is probably in the state of carbonate of soda.

"Chloride of sodium.

"A small quantity of free sulphuretted hydrogen.

"Traces of sulphate of soda and magnesia.

"When boiled down it exhibits strong alkaline properties. Its medical properties are a mild laxative; a diuretic, antiscorbutic, slightly alterative and strongly antacid. This spring rises from the slate at the base of a ridge of quartzose sandstone.

"There are also several other mineral springs in this neighborhood, in Polk county. One at Samuel Gray's on section 20, Township 5 north, Range 29 west, its temperature 58°, the air being 52° (also known as Shurd's Sulphur Spring, G.H.A.). The main characteristic constituents of this water are:

"Carbonate of soda.

"Chloride of sodium.

[1] *Geol. Surv. of Ark.*, An. Rep. for 1891, Vol. i, p. 111.

[2] *Second Geol. Surv. of Ark.*, 1860, p. 97.

"Sulphuret of sodium.

"Traces of sulphate of soda.

"Traces of sulphate of magnesia.

"Its medical properties will be found to be analogous to those of Baker's Spring.

"Nathan Aldridge's Sulphur Spring contains the same constituents, only differing slightly in the proportions."

As shown in Pl. ii, these springs all rise from the same layer of shale.

The principal constituents of the Gap Springs are given by Owen as:

"Chloride of sodium.

"Sulphate of soda.

"Sulphate of magnesia.

"Bicarbonate of alkali.

"And probably a little sulphuret of alkali.

"A trace of carbonate of lime."

An examination of the so-called alum spring gave indications of the same ingredients, with the exception of the absence of sulphur, the presence of iron and a larger proportion of sulphates. These waters will have a mild, aperient effect, combined with a slight alterative action on the system."

Tyra springs in 5 S., 32 W., section 2, consist of a number of springs on the north bank of a small tributary of the Rolling Fork of Little river just west of Hatton Gap. The south bank and bed of the stream are novaculite, so that they appear to come from a layer of shale immediately overlying the novaculite.

Bog Springs are located in the pass of Cross creek through South or Bog mountain on the west side of the creek. They flow out from the foot of the mountain only a few yards from the creek. The principal spring forms a considerable bog.

As a rule, this area of Carboniferous rocks is well supplied with springs, and the streams are remarkably clear and the waters soft.

Stated Meeting, May 21, 1897.

Vice-President PEPPER in the Chair.

Present, 32 members.

The Proceedings of the Officers and Council were submitted.

Pending nominations Nos. 1376 to 1388 were read and, except No. 1380, action on which was postponed, were spoken to. Secretary Frazer and Dr. Morehouse were appointed tellers, and an election for members was held.

Dr. Morehouse read an obituary of the late Lewis A. Scott, Esq.

Mr. Prime offered the following resolution, which was adopted :

Resolved, That a Committee of three be appointed by the President to consider and report on the advisability of offering to coöperate on behalf of this Society with the Royal Society of England in the preparation of an International Catalogue Raisonné of all scientific publications, and that such Committee shall be authorized to communicate with the Committee of the Royal Society on this subject."

Mr. George F. Edmunds made a communication on International Arbitration, which was discussed by Dr. Pepper, Mr. Wharton and Mr. Edmunds.

Dr. William H. Furness, 3d, then made a verbal communition, entitled, "Further Glimpses of Borneo," with lantern slides.

A paper by Dr. Charles E. Sajous on "Solar Heat and Universal Gravitation—A New Working Hypothesis," was then read.

Dr. Greene, on behalf of the Library Committee, offered the following resolutions :

That authority be given to the Library Committee to present one of the duplicate copies of the Treaty of Peace with Great Britain, printed in Paris in 1783, to the library of the Department of State, and one to the Historical Society of Pennsylvania, if they do not already possess copies.

Adopted.

That authority be given to the Library Committee to extend the time after one o'clock, during which the Library shall be open to such hours as they may see fit, provided that no additional expense be incurred.

Adopted.

The Tellers of Election reported that the following Candidates had been duly elected to membership in the Society:

Lord Lister, London.
Prof. W. C. Roentgen, Würzburg.
Owen Wister, Philadelphia.
Samuel N. Rhoads, Philadelphia.
Fridtjof Nansen, Lysaker, Norway.
Stewart Culin, Philadelphia.
S. F. Peckham, Ann Arbor.
Charles F. Mabery, Cleveland.
Edward Orton, Columbus, O.
Prof. Theodor Tschernyschew, St. Petersburg.
Prof. A. Karpinsky, St. Petersburg.
Theodore N. Ely, Philadelphia.

Dr. Hays offered the following resolution:

That a Committee of five be appointed by the Chair to consider and report upon the present status of the Magellanic Premium, and whether anything can be done to more fully carry out the original intentions of its founder.

Adopted.

The Society was then adjourned by the presiding officer.

INTERNATIONAL ARBITRATION.

BY HON. GEORGE F. EDMUNDS.

(Read May 21, 1897.)

The subject of international arbitration is becoming more and more interesting, and possibly, in view of its latest developments, somewhat more difficult of realization.

The idea of arbitration, whether between individuals or nations, necessarily implies a state of difference in respect of rights or duties. In the municipal State these rights are established or defined by municipal law, either written or unwritten, and they are compulsory in the sense that the aggrieved individual may appeal to the power of the State to compel a recognition of his rights or a redress for his wrongs.

This principle is equally true in respect of its nature as between sovereign and independent States, with the exception that there is no common tribunal yet established which has the authority to decide upon, and much less compel obedience to, these principles.

The idea, therefore, of international arbitration presupposes that there must be some rule or law that is to be the standard by which to measure the disputed rights or duties that may be drawn in question between sovereign States.

These rules or laws are what we call international law. It is not founded in any essential sense upon the same grounds as is municipal law, for that is founded upon the assumed consent of all the people who compose an organized State to which they have given the authority, through their representatives of whatever kind, to declare what their conduct toward each other shall be.

International law, therefore, which is to be administered through international arbitration, unless there be special provision made in an agreement for arbitration other or further than what international law requires, is really and in its widest aspects the law inherent in the nature of man; that is natural law, as it is called by the writers. And this natural law may be reduced to its last and best analysis in the statement, which is the foundation of all practical religion, that every man and nation should do to another that which he or it would wish another to do to himself or itself.

But the law of nations has undergone—as have the social conditions of mankind in the long centuries that have preceded us—a great improvement. Some of the earliest writers on the subject have undertaken to defend the use of poisoned weapons in war; later writers have been shocked at such propositions, as, justly, they should have been. An interesting and comprehensive discussion of the nature and history of natural and international law was given by Vattell a century and a half ago, and it may be found in the Preface to the comparatively recent editions of his treatise on the law of nations.

I affirm (notwithstanding the doubts in this respect of very eminent and able gentlemen expressed within a year or two) that there is such a thing as international law that is just as binding upon independent nations in every sense as is municipal law upon the individuals composing a State. It is true that this international law cannot be adjudged in particular cases by a preëstablished tribunal or executed by a sheriff or constable. But it is not the less binding upon the moral sense or honor (if there be any difference in the expression) of every nation having relations with another.

The progress of civilization has been such that nations have come more and more to feel the necessity of, and their obligation to obey, the fundamental principles of justice that every one will admit exist between individual men in a state of nature. Men in a state of nature have found that they could not exist safely and make progress without the establishment of associations respecting common rights and duties which we call States. Thus associated, they bear the same relations as States to each other that they bore toward each other in a state of nature; that is, the duties of justice and right. In their formation of States as between each other, they have agreed to establish tribunals to determine rights and to establish authority to compel respect of such rights. The law of nations imposes the same duties and obligations between nations, but it lacks the compulsory power referred to.

This state of things, then, leads at once, and logically, to international arbitration.

I think no one can state a difference in principle between the duties of men toward each other in an organized State and the duties of nations toward each other, although they do not have a federation possessing the power of judgment and coercion through tribunals appointed to decide and powers authorized to execute the decision.

Thus, in the present condition of the world, international arbitration is the only resource short of the *ultima ratio regum* through which disputes between nations that shall have failed to be adjusted through diplomatic means can be determined.

Why is it that it so often happens that arbitration in the place of war does not take place? It is obviously for the reason that the various organized nations of the world are so suspicious of each other that they are not willing to submit their differences to any common tribunal in the brotherhood of nations.

Take, for illustration, the present condition in eastern Europe and western Asia. The United States, having no possible selfish interest (just or unjust) in the question, might have been appealed to in the person of their chief magistrate to decide, upon due hearing and consideration, what were the respective rights of Greece and of Turkey in Crete, and what were the respective adjustments that ought to be made in respect of European interests in the passage from the Black Sea to the Mediterranean, and in the passage from the Mediterranean to the Red Sea. Had the powers interested in this most difficult question been willing to submit to the United States, or to any other unbiased power, or to a tribunal composed from several States, these perpetual and burning questions which continually involve not merely public war but animosities affecting large communities, unmeasured disaster of life and peace and property might have been avoided. And so it is everywhere in all the frictions and differences that exist in the relations of independent States. The fundamental difficulty is in their want of confidence in each other. The Senate of the United States, I am grieved to say, has very recently demonstrated this want of confidence in any tribunal of an international character to which it should be willing to refer differences even of a very narrow range that might arise between ourselves and that power whose colonies and dependencies are everywhere, and upon whose flag the sun never sets. It may be that motives and considerations less broad than those I have stated have led Senators, as it is reported, to refuse assent to the recent arbitration treaty with Great Britain. And, if this be so, there may be ground for the hope that at some near day in the future this great nation will not be content to rest itself alone on its physical strength, but upon the justice of its cause determined by arbitration in many matters of difference that may arise with another nation, and that in such a case it will be willing to believe and to act upon the belief, that strength is not the absolute test of justice and right, and that the strongest power may sometimes be in the wrong; and, therefore, be willing—strong as it may be—to have its disputes determined by impartial international judges, rather than by the arbitrament of war, with all its miseries.

PROCEEDINGS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY

HELD AT PHILADELPHIA FOR PROMOTING USEFUL KNOWLEDGE.

VOL. XXXVI. DECEMBER, 1897. No. 156.

Stated Meeting, September 3, 1897.

Vice-President PEPPER in the Chair.

Present, 26 members.

Mr. S. N. Rhoads, a newly elected member, was presented to the Chair, and took his seat.

Acknowledgments of election to membership were read from Mr. Owen Wister, Prof. Orton, Mr. Ely, Mr. Rhoads, Prof. Mabery, Mr. James Bryce, Lord Lister, Prof. Peckham, Dr. Nansen, Prof. Karpinsky and Prof. Tschernyschew.

Correspondence was submitted and donations to the Library were reported—the latter included a very valuable gift of sixty-two volumes and ten pamphlets of the publications of the British Museum, from the Trustees, for which a special vote of thanks was ordered to be transmitted to them.

The announcement of the decease of the following members was made:

Dr. Don Crescencio Carrillo y Ancona, Bishop of Yucatan, on March 19, 1897, æt. 59.

Prof. Johannes Japetus Steenstrup, Professor of History at the University of Copenhagen, on June 20, 1897, æt. 84.

Alfred M. Mayer, Professor of Physics in Stevens Institute of Technology at Hoboken, on July 13, 1897, æt. 61.

Dr. Frederick D. Stone, Librarian of the Historical Society of Pennsylvania, at Philadelphia, on August 12, 1897.

J. Sergeant Price, Esq., Treasurer of the Society, at Cape May, N. J., on August 16, 1897, æt. 66.

A communication for the *Transactions* was presented from Mr. John Van Denburgh, entitled, "Some Experiments with the Saliva of the Gila Monster (*Heloderma suspectum*)."

The following communications were read:

By Dr. N. F. Drake, a paper on "The Geology of the Indian Territory."

Mr. Clarence Alve, "Magnetism in Space."

The Finance Committee presented a report, announcing the death of the Treasurer of the Society, J. Sergeant Price, Esq.

It was ordered "that the Finance Committee be and is hereby authorized to draw upon the funds of this Society for the money necessary to pay the current expenses, and to receive its income during the vacancy in the office of Treasurer of the Society, and the said Committee is authorized to have possession of the financial papers and securities of the Society, until such vacancy shall be filled."

The Society was adjourned by the presiding officer.

A GEOLOGICAL RECONNAISSANCE OF THE COAL FIELDS OF THE INDIAN TERRITORY.[1]

BY NOAH FIELDS DRAKE.

(*Read September 3, 1897.*)

INTRODUCTION.

During the spring, summer and fall of 1896, the writer spent six months making a geological reconnaissance of the larger part of the Coal Measures and adjacent formations of the Indian and Oklahoma Territories. The best maps that could then be had of the region were exceedingly inaccurate. In connection with geologic observations, sketch maps were therefore made of areas that were especially important. Nearly all the area south and east of the Canadian river, shown on the accompanying map, was sketched

[1] A thesis for the degree of Doctor of Philosophy, presented to the Department of Geology of the Leland Stanford, Jr., University, May, 1897.

and studied rather closely, partly because the coal beds of that area are valuable economically, and partly because the folded structure and the resulting topography are of special geologic interest. The bordering areas of the Boone chert and limestones were studied because these beds have a wide distribution, and a knowledge of their relations to overlying beds was essential to an understanding of the structure of the area and of the conditions of deposition.

PART I.

Structural Geology.

Area of the Reconnaissance.—The area over which the reconnaissance was made includes the northern part or nearly half of the Indian Territory, and a little of the adjoining part of Oklahoma. It includes the Cherokee, Creek and Seminole Nations, all the Indian Nations in the northeast corner of the Indian Territory, the northern part or nearly one-third of the Choctaw Nation and a little of Oklahoma adjoining the Creek and Cherokee Nations.

The area is about 165 miles long and about 125 miles wide and covers a little more than 20,000 square miles.

Previous Investigators.—In 1819, Thomas Nuttall[1] made several excursions across this region to study its botany and geology. He passed over the country southwest of Ft. Smith, Ark., between Sugar Loaf and Cavaniol mountains[2] and across Winding Stair mountains; then he went up the Arkansas river to Verdigris river and across the country in a southwesterly direction from Verdigris river. He also went up Grand river to the Salt springs and made short excursions in the vicinity of Salisaw and Lee's creeks. His conclusions regarding this field were: that sandstones, shales and coal-bearing rock extend over most of the area; that limestones and cherts all lie north of the Arkansas river; that the salt-bearing strata of Grand river are different from the salt-bearing red beds in the southwest, and that the mountain chains in central western Arkansas and central Indian Territory have a southwest trend.[3]

[1] *A Journal of Travels into the Arkansa Territory*, by Thomas Nuttall, Philadelphia, 1821, pp. 146–177.

[2] *Cavaniol, Caveniol* and *Kavanaugh* are the different ways of spelling the name applied to the mountain lying between the Sugar Loaf and the Sans Bois mountains. *Cavaniol* is the oldest spelling of the name that has been found, and is the one used in this report.

[3] *Jour. Acad. Nat. Sci.*, Vol. ii, p. 49.

In 1822, Edwin James[1] published a geologic section and some explanatory notes of that part of this country lying along the 35th parallel of north latitude. This publication, however, gave very little additional information concerning the geology of this area since it only showed the Ozark mountain strata to be Carboniferous, and the rocks of the Canadian river country to be red beds bearing salt and gypsum.

In 1853, important geologic observations in this country were made by Jules Marcou,[2] geologist to the Pacific Railroad Expedition. His reconnaissance in this field was principally confined to the area lying immediately south of the Arkansas and Canadian rivers. The important additional geologic knowledge he gave of the area was: a better knowledge of the coals, the lithology, and the structure along the line of reconnaissance. He considered the Ozark mountain area an outlying or second fold of the Allegheny mountains.[3]

George G. Shumard made the statement before the St. Louis Academy of Science, in 1857, that he had traced the coal fields from Ft. Smith, Ark., to Ft. Belknap, in Texas.[4] He apparently did not note the break in outcrop of these beds in the southwestern part of the Choctaw Nation, where the Carboniferous is concealed by the overlying Cretaceous.

In 1890, H. M. Chance[5] published "The Geology of the Choctaw Coal Fields," which is the most valuable information yet published on the geology of this area. In this paper he locates the relative stratigraphic position in the Indian Territory of the three productive coal beds, and clearly outlines by description, sections, and maps, most of the Grady and McAlester coal beds along the outcrop from six or seven miles west of McAlester to near the Poteau mountains. He gives a section from the base of the Grady coal bed to the top of Cavaniol mountain, which includes the productive part of the Coal Measures. He also notes the prevailing S. 80° W. axes of folds and the system of southwest folds.

In 1891, R. T. Hill[6] published a paper outlining the Ouachita

[1] *Jour. Acad. Nat. Sci.*, Vol. ii, pp. 326–329.

[2] *Pacific Railroad Reports*, Vol. iii, Part iv. pp. 123–127.

[3] "Esquisse d'une classification des chaines de montagnes d'une partie de l'Amérique du Nord," *Annales des Mines*, 5 me. sér., Tome vii, pp. 339, 340.

[4] *Trans. Acad. Sci.*, St. Louis, Vol. i, p. 93.

[5] *Trans. Amer. Inst. Min. Eng.*, 1890, Vol. xviii, 653–661.

[6] *Amer. Jour. Sci.*, Vol. xlii, August, 1891, pp. 111–121.

Mountain System in the Indian Territory, which further classified the knowledge of this system.

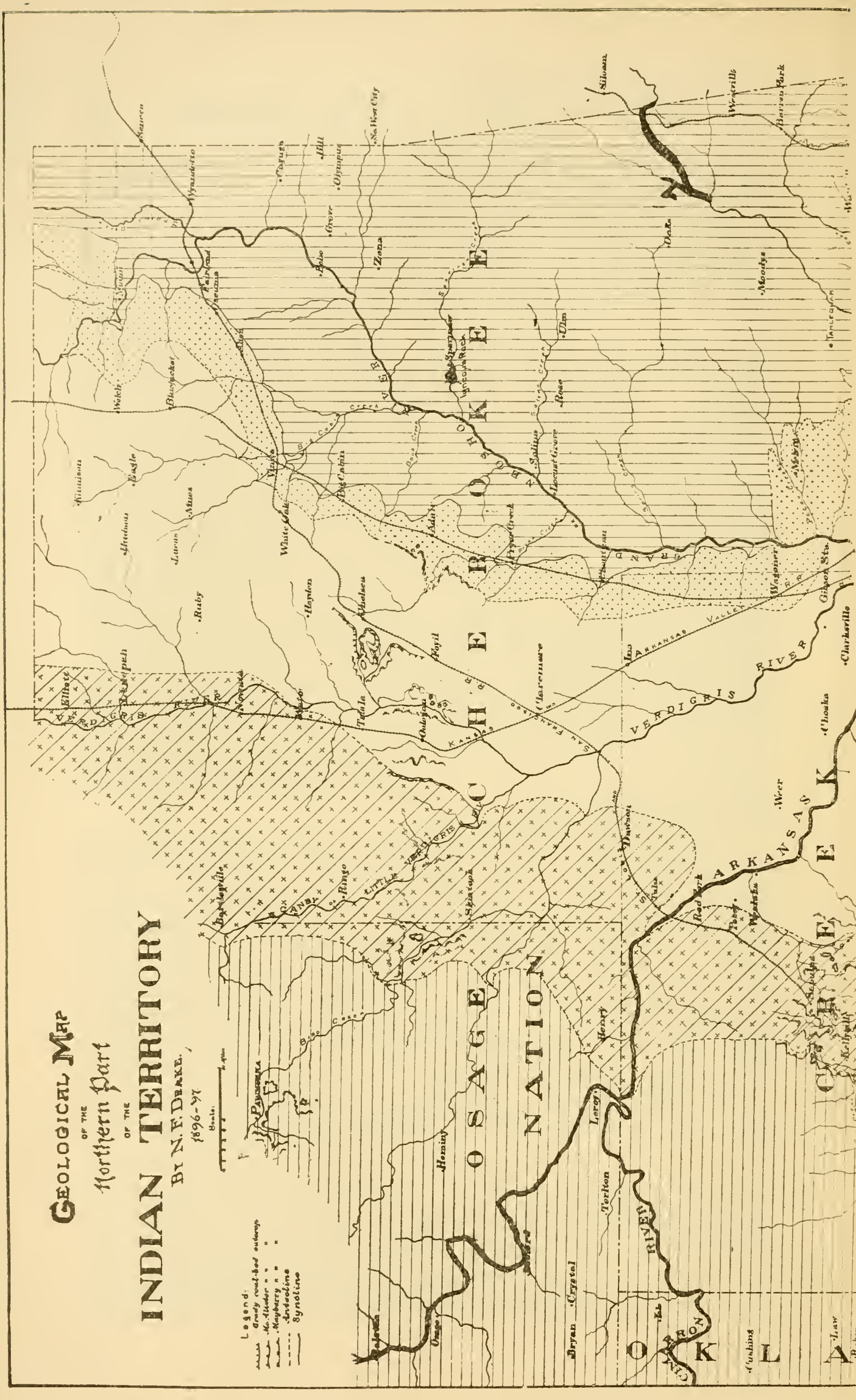
The work of the Arkansas and the Texas geological surveys, the geologic investigations in southeastern Kansas by Prof. Charles S. Prosser, and an unpublished sketch map kindly furnished by Prof. Orestes St. John, showing the general distribution of the geologic formations in the Indian Territory, further assisted in giving an idea of the geology of this area. Taken as a whole, however, the field was comparatively a new one to geologists and it is rather remarkable that it should have so long remained so little known.

Hydrography.—Nearly all of the area under consideration is drained by the Arkansas river and its tributaries. A very little of the southern part, however, is drained by streams tributary to the Red river. The Arkansas river enters the country under discussion a little south of the northwest corner, and runs in a southeasterly direction, thus crossing it diagonally through the central portion. To the north of this river the larger streams, the Illinois, the Grand, the Verdigris, and the Little Verdigris or Caney rivers, flow nearly southward and empty into the Arkansas river. The Illinois river, however, is somewhat deflected to the westward, and the Verdigris and Caney rivers deflected to the eastward. The streams on the north thus have a tendency to flow into the Arkansas river at the same locality.

To the south of the Arkansas river the Cimarron and the Canadian rivers are its largest tributaries. The Cimarron, the most northerly of the two, flows eastward into the Arkansas river, while the Canadian river is slightly deflected to the north in its eastward course, and enters the Arkansas river about twenty miles below the collecting basin of the streams to the north. Between the Cimarron and Canadian rivers, the Deep Fork and North Fork of Canadian rivers, flow almost eastward and unite a short distance above their confluence with the Canadian.

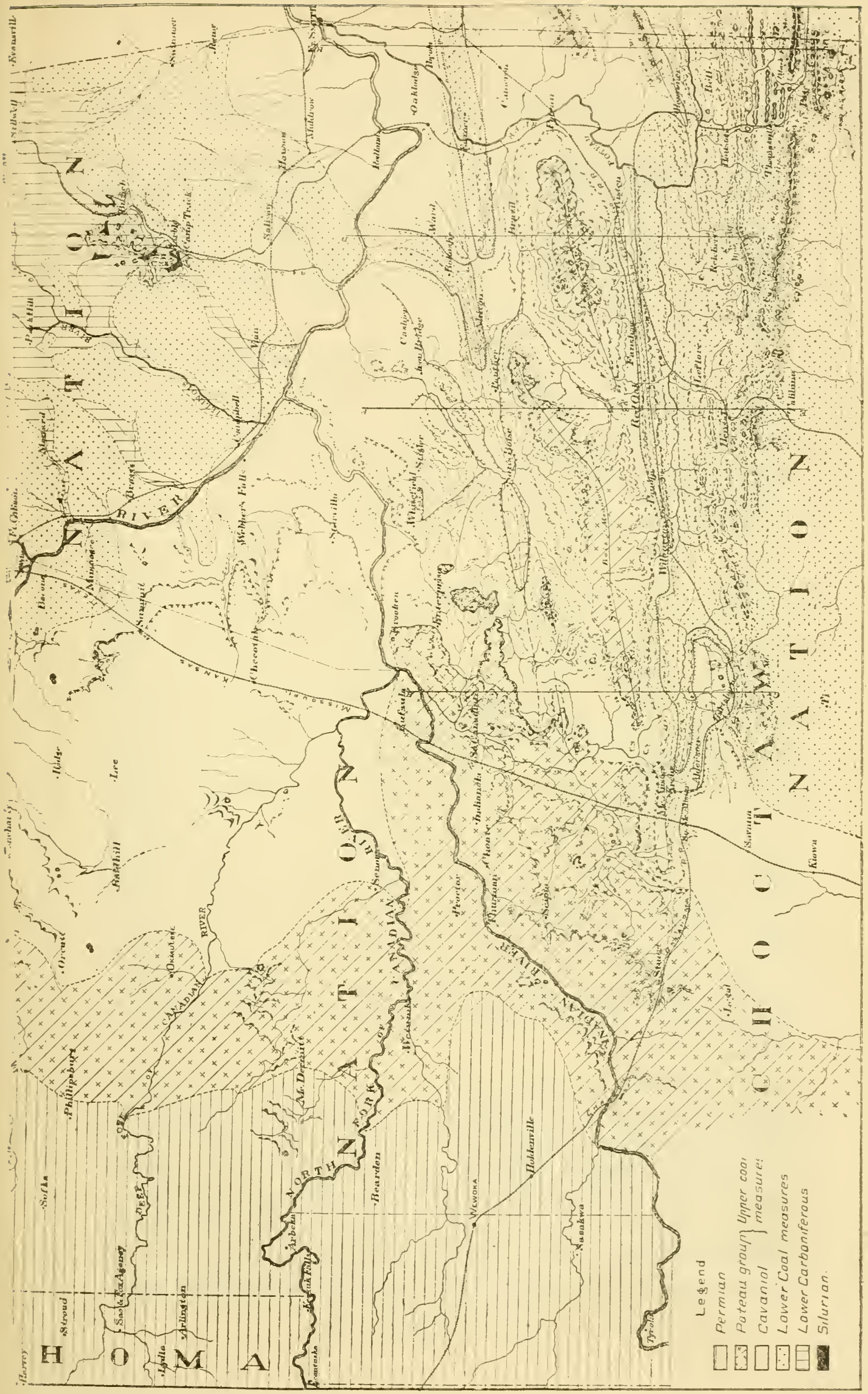
Topography.—There are three general topographic groups in this area. One is the elevated and folded area to the south, which is an extension of the Ouachita mountain system; a second group is the elevated plateau area in the northeast, which widens slightly southward to near the Arkansas and the Grand rivers. This belongs to the Ozark plateau system. The third group is a broad plain-like area that slopes gently eastward in terrace-like escarpments and undulations, and narrows into the low depression between the Ozark

Plate I.



Geological Map
of the
Northern Part
of the
INDIAN TERRITORY
By N. F. Drake.
1896-97
Legend:
Anticline
Syncline
CHEROKEE
OSAGE NATION
CREEK
OKLA
VERDIGRIS RIVER
ARKANSAS
GRAND
Vinita
White Oak
Wyandotte
Bartlesville
Claremore
Clarksville
Chouska
Hominy
Pawhuska
Cushing
Siloam
Westville
Moodys
Tahlequah
Tulsa
Red Fork
Dawson
Choteau
Bryan
Crystal
Blue Jacket
Welch
Eagle
Ruby
Hayden
Big Cabin
Adair
Pryor Creek
Locust Grove
Rose
Ulm
Zena
Grove
Olympus
Afton
Fairland
Oowala
Talala
Sapulpa
Kellyville
Leroy
Henry
Skiatook
Ringo
Oak
Kansas
Mulhall

Plate 1.


Legend
Permian
Pateau group
Cavanial
Upper coal measures
Lower Coal measures
Lower Carboniferous
Silurian.

and the Ouachita mountain systems. The westward deflection of the Illinois and Grand rivers is due to the Ozark uplift, while the northern deflection of the Canadian river is caused by the uplifted folds of the Ouachita mountain system. Thus the rivers approach each other on either side of the Arkansas river along the border lines of these topographic groups.

The Ozark Mountain System.—This term was formerly applied to the mountainous area of southern Missouri, northwestern and central western Arkansas and east central Indian Territory. The name is, however, properly restricted to the plateau or northern part of this area, and the name, Ouachita, has been applied to the folded mountains of the southern part of the area.

The Ozark mountains in the Indian Territory are divided into two distinct topographic areas. One lying east of Grand river and north of Tahlequah and Evansville is the lower table-land of the two, and contains flat lands and also areas of sharp narrow ridges and small V-shaped canyons. The other portion of the Ozark system is more elevated and is the western prolongation of the Boston mountains. This area is triangular in shape; the apex of the triangle is about four miles southeast of Fort Gibson, the base lies south of Evansville, and is about fifteen miles across, measured along the Arkansas-Indian Territory line. This table-land is about 1500 feet above tide-level. It is usually bounded by steep escarpments on the north side and by both escarpments and slopes on the south. Several streams have cut through this plateau and at present flow through narrow valleys or canyons. The escarpment on the north side of the Boston mountains has a general east-west direction, but it is a very irregular line with plateau tongues and outliers extending northward along the face of the mountain; these are erosion remnants showing the former extension of the lower carboniferous strata.

The Ouachita Mountain System.—The elevated topographic group in the southern part of the field is an extension of the Ouachita mountain system which forms such a typical area of folded strata and parallel ridges and valleys in western Arkansas. This system was named[1] by Dr. J. C. Branner, who thinks it is an outlier of the Appalachian system and the structural equivalent of the Cincinnati-Nashville anticline. The Appalachian system, he thinks, once extended across the Mississippi Valley south of the Ouachita moun-

[1] *Ann. Rept. Geol. Surv. Ark.*, Vol. ii, 1888, p. 175.

tains, through Mississippi, Louisiana and central Texas.[1] There are two principal types of mountains in the Ouachita system; one of these consists of long ridges, the other is the bench-and-bluff and flat-topped mountain type. The mountains, ridges and valleys of this region trend almost east and west, corresponding to the folds.

The Canadian river and the Arkansas river from the mouth of the Canadian river to Arkansas, practically form the northern boundary of this group. For some fifteen to twenty miles south of these rivers low isolated buttes, table-lands and ridges such as Long mountain, the Seven Devils, McChar mountains and Backbone mountain are the outliers to the typical part of the mountain system. Immediately south of these outliers are the Sugar Loaf, the Cavaniol and the Sans Bois mountains, each rising nearly 3000 feet above tide-level. They all trend about S. 80° W., but are completely separated.

These three mountains, together with the Poteau mountains, and many smaller elevations, are of the bench-and-bluff type. The mountains farther to the south, the Walker, the Blue, the Winding Stair, the Black Fork and the Rich mountains are of the ridge type.

Prairie Plains.[2]—The third topographic division comprises all the country north of the Canadian river and west of Grand river. The predominant topographic feature of this division is a broad southeastward sloping plain, broken by gentle irregular undulations and by long lines of escarpments facing east or east-southeast. Of these features the east-facing escarpments are the most conspicuous. They are usually but fifty to one hundred feet high, although often from ten to fifteen miles long, and even much longer if local breaks are not taken into account. Occasionally gentle westward slopes extend from the top of one escarpment back to the base of the one next west of it, but usually the inclination is not sufficient to bring the base of the western escarpment down to the level of the eastern one.

Structure of the Topographic Groups.—In each of these topographic groups the geologic structure accounts for the topographic forms. The plateau type in the northeast has its strata almost horizontal; the folded type in the southern part of the field has its strata irregularly folded along nearly parallel lines; in the western

[1] *Proc. Bost. Soc. Nat. Hist.*, Vol. xxvi, p. 477; *Am. Jour. Sci.*, November, 1897, pp. 357–371.

[2] J. W. Powell, *National Geogr. Monographs*, Vol. I, No. 3, p. 83.

part of the field the escarpments and undulating topographic features are due to the varying resistant power of gently westward dipping beds.

Ouachita Mountain Structure.—In the central and northern part of the Ouachita area the mountains and mesas are practically all synclinal in structure, and the deeper and broader synclines form the larger mountains, such as Sugar Loaf, Poteau, Cavaniol and San Bois mountains; the mesas, such as the Seven Devils and McChar mountains, occupy the smaller synclinal folds. In the southeastern part of the field all the mountains and ridges are upturned edges of extensive hard rock beds. There is every gradation from the sharp ridge with equal slopes on either side and its steeply dipping strata, to the escarpment or bench topography with its gently dipping beds.

Ouachita Valley Structure.—In the central and northern part of the Ouachita area most of the larger valleys lie along anticlinal axes, while in the southeastern part of the field the valleys are in the softer strata or along faults, and are nearly always parallel to the structural lines.

Folds and Faults.—The folds and faults belong principally to that part of the field included in the Ouachita mountain system. The limits of the folded area are not sharply marked, however, and there are isolated folds and faults through and around the Ozark mountains. There are two distinct systems of folds, a primary system and a secondary one. The axes of the most characteristic or primary system run about S. 80° W. The axes of the secondary system run approximately northeast–southwest, but the different folds of this system vary much in direction on either side of the general direction. It does not appear that these two systems of folds are of different ages, because the topographic features have developed equally along corresponding kinds of folds regardless of the direction of their axes, and also because the two systems are intimately related, as is shown by certain folds lying in both systems. As already stated, the axes of the principal folds run nearly east and west and the folds are quite regular. The distinctness of the secondary folding is shown by the general southwest direction of many axes and by the west-northwest dip of all the rock beds in the central and western part of the whole area of the reconnaissance. These western beds dip nearly northwest in the southern part of the area, to the west-northwest in the central, and to the west in the northern part of the Indian Territory. Thus the strike swings around so as to become parallel to the western end of the Ozark mountain uplift. This secondary system of folds is more characteristic of the northern part of the region, thus further showing its intimate connection with the Ozark mountains. So it appears that the force that threw the Ouachita mountain system into east and west folds at the same time uplifted the Ozark mountains to the north and started secondary north-south folds.

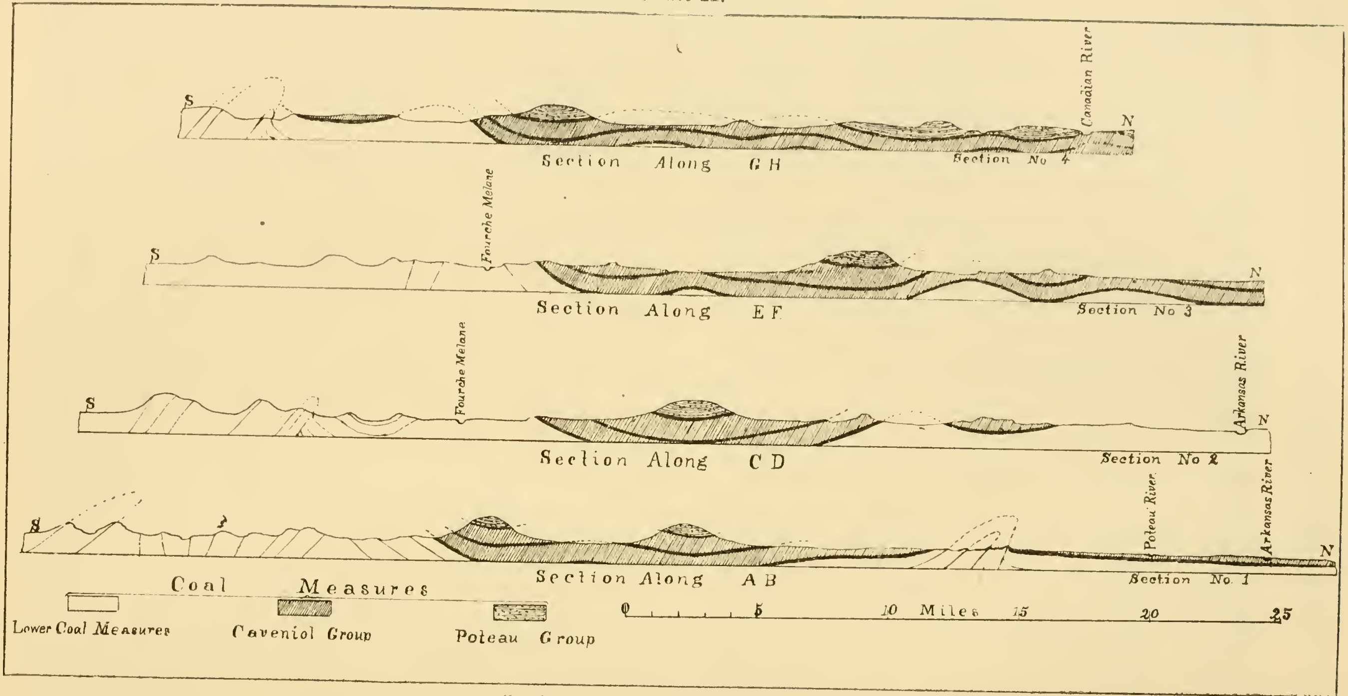
The sketch map of the Choctaw coal field shows that there are three groups of the south 80° west folds that are especially prominent. The group on the north is anticlinal and runs westward from immediately south of Pocola, passing near Farmer and Milton, and running through Sans Bois to the west end of Sans Bois prairie. This group includes three separate anticlinal folds, or the Backbone, the Bokoshe-Milton and the Sans Bois anticlines.

The group lying immediately south of this is composed of three separate synclines, the Sugar Loaf, the Cavaniol and the Sans Bois synclines, giving axial direction to the mountains of those names. The third group, farther to the south, is anticlinal and extends from immediately north of Heavener westward, with some minor deflections, passing near Krebs and through McAlester. This is a continuous anticlinal fold. To the north of these three groups the folds are more gentle and irregular, while to the south of them the folding is also more irregular and decidedly more violent and accompanied by faulting. So in the southern part of the field the structure can only be worked out by detailed study.

Folds of the second system, or those running nearly northeast-southwest, are all gentle and not so extensive. The most prominent folds of this system are those separating the Sugar Loaf, Cavaniol and Sans Bois mountains, and those lying between Ward and Whitefield. Of all these the one separating Cavaniol and Sans Bois mountains is the most prominent, and it is only a gentle roll.

Characteristics and Origin of the Folds and Faults.—The intensity of folding and faulting increases quite regularly southward, as is shown in Secs. 1, 2, 3 and 4, Pl. II, and this intensity of folding extends further westward in the southern part of the area. Along any given east and west line the folding is usually more intense to the east; this, however, is due chiefly to the southward deflection of the west end of the principal folds. As a rule, the strata on the north side of anticlinal folds dip more steeply than on the

Plate II.

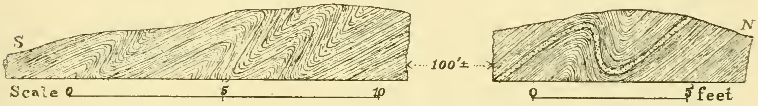


Sections across the Choctaw coal field.

south side of the same folds, as is shown in Secs. 1, 2, 3, 4, 5, 6, 8, and A. This feature is more marked where the folding is intensified. Where the anticlines are very closely pressed, overthrows to the north and often faulting along the north side of the anticlines are the usual consequences; this is shown in Secs. 5, 6 and Pls. II and VII. In the Ozark mountain area the faults are usually normal, while in the Ouachita area the faults are along anticlines.

All mountains of importance in the southern part of the field (Walker, Black Fork, Rich, Blue, Winding Stair, Jack Fork and Kiamichi mountains) have practically all their beds dipping south about 40°. Throughout the area including these mountains, the folds are so closely pressed, overthrown, and faulted that the strata no longer show broad anticlines with low dips.

The elevation of the region, the increased intensity of folding toward the south, and the overthrows toward the north all show an upward and northward movement of the rock beds at the time of folding. In places these movements of the strata have produced wrinkles like that shown in Sec. A.



Sec. A. To illustrate Ouachita folded structure. Sketched from exposures along a railway cut, five miles southeast of Bengal.

This movement has tilted beds 40° to the south, the angle at which they best resisted breaking and crushing. As noted by Marcou,[1] Branner[2] and Griswold[3], these disturbances are probably contemporaneous with the Allegheny mountain uplift, and as noted by Winslow[4] they are probably due to the raising of the isogeotherms in the great thickness of Paleozoic beds.

Lithology of the Area of the Reconnaissance.—This field includes both igneous and clastic rocks. The igneous rocks, however, are confined to one small granitic dike in the Cherokee Nation. Among the clastics, shales, sandstones, limestones and cherts have extensive developments.

[1] *Annales des Mines*, 5me sér., vii, pp. 339, 340.
[2] *Ann. Rep. Geol. Sur. Ark.*, 1890, iii, p. 213.
[3] *Proc. Bost. Soc. Nat. Hist.*, xxvi, pp. 474–479.
[4] *Bull. Geol. Soc. Am.*, 1891, ii, pp 231–234.

Igneous Rocks.

Previous Knowledge of the Igneous Rock.—The existence of igneous rock in the Cherokee Nation has been known for a long time. It was referred to in D. D. Owen's *Second Report of the Geology of Arkansas* as a red granite which occurred at the mouth of Spavinaw creek, some thirty or forty miles west of the Arkansas line. Edward T. Cox failed to find the granite in place, but saw some millstones that were made from it, and obtained specimens which were broken off in fashioning the millstones. He thought this granite underlay the sedimentary rocks of southwestern Missouri and northwestern Arkansas.[2]

The exact locality of this granite outcrop has, however, apparently never been definitely known to any one interested in the geology of the country until 1896, when the writer, after a special search, found the rock in place.

Locality and Mode of Occurrence.—The rock occurs in the Cherokee Nation, on the north side of Spavinaw creek, about six miles from its mouth and three-fourths of a mile west of Spavinaw postoffice. It is a dike about twelve hundred feet long by fifty feet wide. The outcrop is not continuously exposed, but the breaks are probably due to a thin covering of detritus from the clastic rock. There are four exposures of the dike rock, which vary in length from about one hundred to two hundred feet, and occur at intervals of about two hundred feet.

This dike runs along the axis of a gentle anticlinal fold which extends about N. 30° E. The dips of the sedimentary beds on either side of the dike are only 5° to 10°, but the fold is broad and affects the rocks for two to three miles to the west and probably as far to the east. Silurian strata which, over the adjoining country, are usually covered by two hundred to five hundred feet of Lower Carboniferous beds, are here exposed to a depth of about two hundred feet and outcrop in the valley, as shown in Pl. III. The Silurian strata along the contact of the dike appear to be free from any special metamorphic action due to the dike rock.

Macroscopic Characters.—The general color of the rock is a light brick red with a mingling of black specks which are slightly grouped and in places so much as to give it a somewhat

[1] *Second Report of a Geological Reconnaissance of the Middle and Southern Counties of Arkansas, 1859 and 1860*, pp. 404, 408.

[2] *Ibid.*, p. 408.

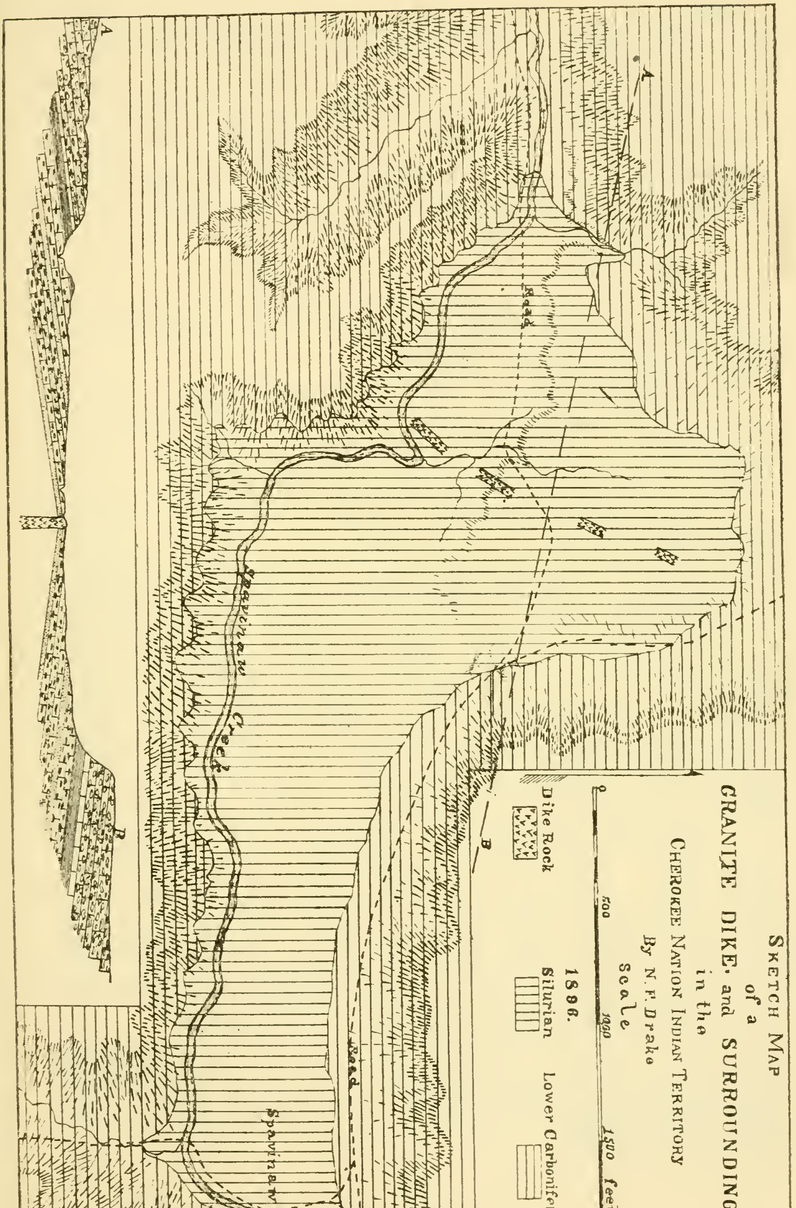

Sketch Map
of a
GRANITE DIKE and SURROUNDINGS
in the
Cherokee Nation Indian Territory
By N. F. Drake
Scale
0 500 1000 1500 feet
1896.
Dike Rock
Silurian
Lower Carboniferous
Spavinaw Creek
Road
A
B

Plate III.

mottled appearance. In the red color are blended a light pink and also deeper red, due to the feldspar crystals, which are red and form by far the larger part of the rock. The black specks are small magnetite crystals. Associated with the black crystals are greenish hornblende and chlorite crystals, which give a greenish tint hardly noticeable on a casual observation. It contains also a few small white quartz crystals. The crystals composing the rock vary in size from those which give a general granular appearance to the ground mass to feldspar crystals that are 1 c. m. or more in length. The freshly broken rock shows a general fine-grained, somewhat shiny and bright appearance with numerous shining crystal faces of the larger feldspars.

Microscopic Examination.—Feldspars, quartz, chlorite and magnetite are the principal minerals of the rock, while hornblende and epidote occur sparingly. A holocrystalline texture is shown throughout the rock. The most striking and general microscopic feature is its granophyric and micropegmatitic texture. Through most of the orthoclase crystals quartz is intergrown in the most intimate manner, so that each feldspar shows radiating or parallel alternating quartz and feldspar in narrow bands, which form fan-shaped or irregular patches. In other cases, the quartz appears in triangular sections along lines through the feldspar crystals, or is micropegmatitic. In any given feldspar crystal, the included quartz plates or prisms show the same orientation. Quartz occurs sparingly isolated in larger crystals, but very rarely shows its outlines. Feldspars are the predominant minerals. They are principally orthoclase, but plagioclase feldspars are of rather common occurrence. The feldspars have a fine granular appearance and a reddish color. Phenocrysts of feldspar are quite common; they, however, generally show irregular outlines instead of crystal faces. Magnetite occurs in small opaque masses, many of which show perfect crystal outlines. They show a slight grouping through the rock and in places give a blended appearance to the crystals.

The hornblende is the greenish variety and of rather uncommon occurrence. The chlorite is common and occurs in greenish bands, spherular aggregates and in minute particles. Epidote is of rather common occurrence.

Chemical Analysis.[1]—

	PER CENT.
Loss on Ignition	1.11
Silica (SiO_2)	71.10
Ferric Oxide and Alumina (Fe_2O_3 and Al_2O_3)	20.60
Calcium Oxide (CaO)	2.53
Magnesium Oxide (MgO)	0.99
Potassium and Sodium Oxide (K_2O and Na_2O)	3.76
Total	100.09

Classification of the Rock.—The high percentage of silica, the holocrystalline texture and the general interference of crystallization shown in the irregular crystal outlines at once place the rock in the granitic series. As shown by the feldspars, quartz and magnetite, however, there is a strong tendency to the porphyritic texture: it is, therefore, a porphyritic granite. The minute textures of the feldspars and quartz is designated by the name granophyre.

Age of the Dike.—As noted above, the dike breaks through Silurian strata along the axis of an anticlinal fold. The Lower Carboniferous strata overlying the Silurian are tilted by this fold. The igneous rock was, from this evidence, most likely protruded at the time of the folding. This anticline is one of the outlying folds of that mountain system which is such a marked feature of central western Arkansas and the adjoining part of the Indian Territory. This system of folding is post-Carboniferous, pre-Cretaceous and quite likely pre-Mesozoic, because Upper Coal Measures deposits are folded, Lower Cretaceous deposits lie almost undisturbed upon these folds and no Jurassic or Triassic beds occur over the area.

Relation to the Igneous Rocks of Other Areas.—This dike in the Cherokee Nation is equally distant from three different igneous rock areas, and about two hundred miles from either of them. One lies in southeastern Missouri, one in central Arkansas and the other in the Choctaw and Chickasaw Nations, Indian Territory. The igneous rocks of this latter-named area have not been studied by any one sufficiently to make satisfactory comparisons. The igneous rocks of Arkansas are quite different from the Spavinaw granite. Those of Arkansas "belong to the eleolite syenites and their associated dike rocks;" they are gray or blue in color[2] and are post-Car-

[1] Analysis made by Mr. Chester A. Thomas.

[2] *Ann. Rept. Geol. Surv. Ark.*, 1890, Vol. ii, p. 3.

boniferous in age. In texture, color and mineralogical composition many of the Missouri granites closely resemble those of the Spavinaw area. The resemblance is especially true of the granophyric and micropegmatitic texture. Dr. Haworth says:[1] "The distribution of rocks exhibiting such structure is very wide; there is scarcely a granite in the State in which portions of it are not represented. . . . . The small outlying granitic areas generally have this structure throughout. . . . . This structure is common in the porphyries also."[2]

Iron oxide is a rather common constituent of the Missouri granites, and is especially common in the porphyries.[3] These properties in general are also characteristic of the Spavinaw rock. The age of the Missouri granite, however, is apparently different since it has been referred to the Archean.[4]

Clastic Rocks.

The clastic rocks which cover all this area, except the small dike described, belong to the Silurian, the Lower Carboniferous, the Coal Measures and the Permian.

The Silurian occurs in a few narrow valleys in the northeastern part of the area. The Lower Carboniferous covers about half of the Cherokee Nation, or the northeastern part of the field under discussion. The Coal Measures cover all the rest of the area except a narrow strip along the western edge, which is Permian.

Silurian.

The Silurian areas lie in narrow strips along valleys in the Cherokee Nation, where stream erosion has cut down through the overlying Lower Carboniferous beds. In some places folding has elevated these lower beds so that erosion has more readily exposed them.

Structure.—The Silurian strata lie almost horizontal and closely conform to the inclination of the overlying Lower Carboniferous beds.

Lithology.—The strata are composed of saccharoidal sandstones, marble or highly metamorphosed limestones, chert and dolomitic calcareous sandstones.

[1] *Mo. Geol. Sur.*, Ann. Rept., 1894, Vol. viii, pp. 165-166.
[2] *Ibid.*, p. 193. [3] *Ibid.*, pp. 141, 188. [4] *Ibid.*, pp. 95-96.

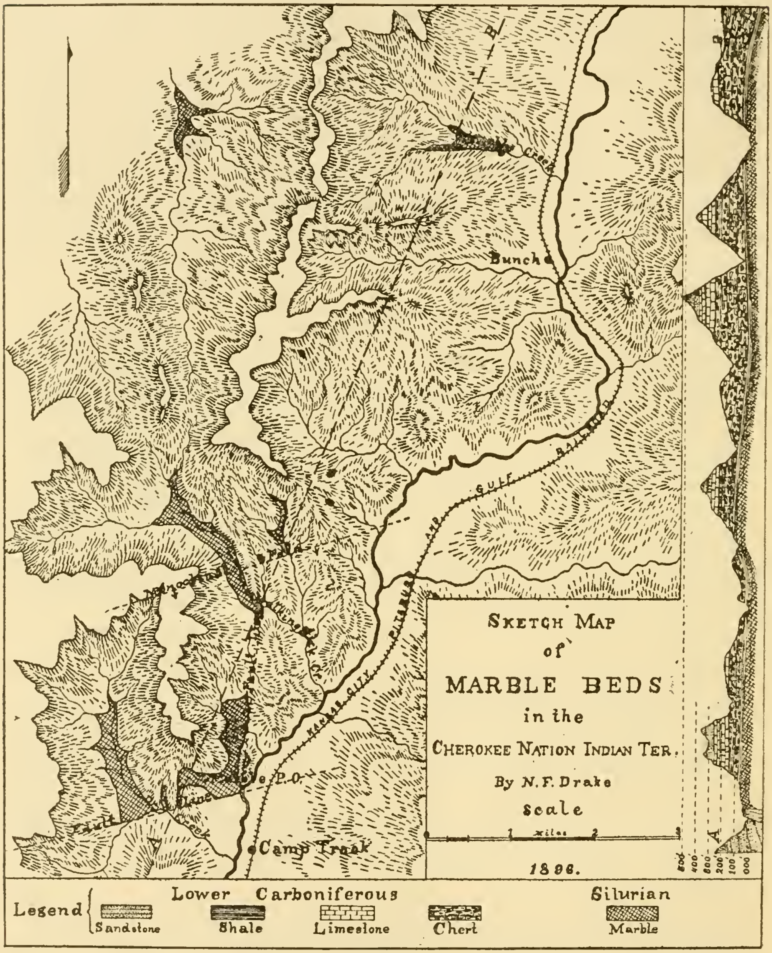
Local Development.—The localities where the writer saw and examined Silurian deposits are on Spavinaw creek six to seven miles from its mouth, along the Illinois river southeast of Oaks, along Salisaw creek at and near Marble and on Elk creek west of Bunch.

Spavinaw Creek Area.—The area on Spavinaw creek is shown in Pl. III. It is about one mile square, and is exposed mainly on account of an anticlinal fold which elevates the beds so that the erosion of Spavinaw creek has reached and cut into them. About two hundred feet of the strata are exposed. The rocks are mainly cherty limestones, cherty calcareous sandstones and saccharoidal sandstones. The lowest exposed strata lie practically in contact with the igneous dike and are composed of fossiliferous chert. Along the creek at Spavinaw post-office twenty feet or more of the Silurian strata are exposed.

Illinois River Areas.—At the Stewie ford of the Illinois river on the Cincinnati-Oaks road, about seventy-five to one hundred feet of Silurian strata are exposed in the bluffs and the hillsides along the valley. These strata are mainly saccharoidal sandstones, rather thin bedded, but sandy clay shale is quite frequently interstratified with the sandstone. These clays are of a light gray color and in places are slightly blue, and some are yellowish. Silurian strata are exposed on the above-named road also about two miles to the northwest of the ford, at which exposure the beds are saccharoidal sandstones dipping slightly to the southeast. Good exposures of the thin bedded sandstone and shales may be seen at the Stewie schoolhouse about one-half mile northwest of the ford. From the exposures seen along and near the river, it seems likely that the outcrops extend several miles up and down the valley from the ford. Silurian strata are reached by this river erosion along the Arkansas-Indian Territory line, and they are nearly reached in the bed of the river east of Greenleaf courthouse, some twelve to fifteen miles southeast of Tahlequah. So it is probable that exposures may be seen for twenty or thirty miles along the river valley within the Cherokee Nation.

Salisaw Creek Areas.—The exposures of Silurian deposits on Salisaw creek were caused by folding, faulting and erosion. The location and areal outcrop of these beds are shown in Pl. IV. The Silurian strata nowhere rise high upon the hillsides, but are almost entirely confined to the deeper erosion channels of the valleys and cañons. They are exposed, however, only where folding or faulting has brought them to a higher level than they would otherwise have reached. There are in this area two systems of folds and fault lines; one runs about 10° south of west, and the other 10° east

Plate IV.



of north. One of the S. 80° W. fault lines runs from a point about one-half mile southeast of Marble P. O. westward across Dry creek. From the first-named point, a fault line runs N. 10° E. across Walkingstick creek, where it meets a monoclinal fold running nearly east and west apparently. The uplift of the monoclinal fold being on the north side, outcrops of the Silurian strata extend farther east on that side of the fold. Another east and west anticlinal fold appears to lie about one mile north of Bunch. Silurian rocks are exposed along this uplift one and a half miles northwest of Bunch, and on Elk creek about six miles W. N. W. from Bunch.

Lithology of the Salisaw Creek Area.—Marble and saccharoidal sandstone are practically the only kinds of rocks exposed in these outcrops. There is, however, a bed of chert some twenty-five feet thick one-half mile west of Marble, which is most likely Silurian. This chert consists of angular pieces, from an eighth to a fourth inch in diameter, of pink and also white chert scattered through a ground mass of gray chert. At the base of the chert bed, there is some saccharoidal sandstone containing chert nodules. The saccharoidal sandstone usually lies at the top of the Silurian beds in this area, and is from one inch to twenty-five or thirty feet thick. The grains composing the sandstone vary considerably in size: the largest are about two millimeters in diameter. These sandstones may be seen along Walkingstick creek above the Marble bed, at almost every place where the top of the marble is exposed. They also outcrop one-half mile east of Marble on Salisaw creek, and northwest of Marble along Dry creek. The marbles are generally of a pink color, rather coarsely crystalline, seamed, and lie in massive beds; twenty-five to thirty feet of massive marble is exposed at all the larger Silurian areas marked on Pl. IV, and the base of the marble was not seen at any place. Mr. J. D. Rice, who quarries marble at Marble P. O., gave me the following section from a drill hole on Dry creek, northwest of Marble P. O.

	FEET.
Pink marble	25
Light gray marble	100
Deep pink marble	2½
Dark gray marble	2½
Deep pink marble	5
Dark gray marble	1

Relation to the Silurian of Arkansas.—A section[1] of the Silurian deposits in Arkansas gives something over one hundred and fifty feet of pink, chocolate and gray-colored marbles on top, which beds

[1] *Ann. Rept. Geol. Sur. Ark.*, 1890, Vol. iv, pp. 10, 11, 214.

are called St. Clair marbles. These beds are underlain by blue and gray limestones called the Izard limestone. The Izard limestone is underlain by saccharoidal sandstones, magnesian limestones and cherts.

All the Silurian deposits seen in the Indian Territory, except the Salisaw and Elk creek areas, are composed of saccharoidal sandstones, cherts and calcareous, magnesian sandstones. The Salisaw and Elk creek Silurian rocks, however, are mainly pink and gray marbles, and therefore appear to be the equivalent of the St. Clair marble, while the Illinois river and Spavinaw creek areas belong to the beds below the Izard limestone.

The St. Clair marbles in Arkansas are principally confined to Independence, Izard, Stone and Searcy counties, in the northern part of the State. The Izard limestones have a somewhat wider range,[1] but neither the St. Clair marble nor the Izard limestones are known as far northwest as Benton county, Ark.,[2] or to the west of Benton county, in the Indian Territory. So it appears that these topmost Silurian beds were eroded in the northwest to a greater extent than they were to the south and east, before they were covered by later deposits. Dr. Henry S. Williams,[3] principally from biological investigations, has determined the top of the St. Clair marble to be of Clinton-Niagara age, and the lower part of it to be of Trenton age. From the thickness of the marble beds in the Salisaw creek areas, as shown by drill holes, it is probable that the outcropping part is the equivalent of the Clinton-Niagara part of the St. Clair.

Lower Carboniferous.

Area.—The Lower Carboniferous is confined to the northeast part of the Cherokee Nation and is roughly bounded on the west by the Grand or Neosho river and on the south by the Boston mountains. This area covers about three thousand square miles, approximately one-half of the Cherokee Nation.

Lithology.—The rocks composing the Lower Carboniferous are cherts, limestones, shales and sandstones.

Structure.—The beds as a rule are practically horizontal, especially in the northeastern part of the area. Along the western border of

[1] *Ann. Rept. Geol. Sur. Ark.*, 1890, Vol. iv, p. 112.

[2] *Ann. Rept. Geol. Sur. Ark.*, 1891, Vol. ii, pp. 27–32.

[3] *Am. Jour. Sci.*, 1894, Vol. cxlviii pp. 328, 329.

the area the strata dip slightly to the west, while along the southern border they are somewhat disturbed by gentle folds which usually run a little south of west by north of east; but many run about northeast by southwest. The general result of the disturbance is to make the strata dip with varying steepness to the south.

Eureka Shale.

This shale is black, argillaceous, bituminous and rather friable and varies in thickness from one inch to forty or fifty feet. It immediately overlies the Silurian beds and is apparently unconformable with them since the shale lies on cherts and saccharoidal sandstones along Spavinaw creek and Illinois river, while about twenty-five miles farther south it lies on higher strata composed of one hundred and fifty feet or more of Silurian marble. Similarly, in Arkansas, the shale lies on top of the St. Clair marble and the Izard limestone along the southern border of the Silurian area, while farther to the north it rests on cherts and saccharoidal sandstones which underlie the marbles and limestones.

The shale is apparently conformable with the overlying beds, since the limestone at the base of the Boone chert was found resting on it at every place where it was seen. The shale may be seen at nearly every locality where Silurian beds are exposed, and at a few places where the erosion has not passed through the shale bed. Quite often detritus from overlying rock beds covers and obscures the outcrop of the shale, but by tracing the horizon a short distance it is usually found.

The Eureka shale has a wide distribution outside of the Indian Territory. It is usually found in northwestern Arkansas wherever the base of the Boone limestone is exposed. From its typical development at Eureka springs, Ark., it was named by Dr. J. C. Branner, the Eureka shale.[1]

Dr. Branner says: "The Eureka shale is clearly the equivalent of the Tennessee bed called by Safford the 'Black shale.'"[2] Safford says this shale also occurs in Virginia, Georgia and Alabama.[3]

[1] *Ann. Rept. Geol. Sur. Ark.*, Vol. iv, 1890, p. 345; "Phosphate Deposits of Ark.," *Tran. Am. Inst. Min. Eng.*, 1896, xxxvi, 580–582.

[2] *Ann. Rept. Geol. Sur. Ark.*, Vol. iv, 1888, p. 26; "The Phosphate Deposits of Arkansas," *Trans. Am. Inst. Min. Eng.*, 1896, xxxvi, 582.

[3] *Elementary Geol. of Tenn.*, by James M. Safford and J. B. Killebrew, Nashville, 1885, p. 75.

The "Black shale" of Tennessee was referred to the Devonian[1] by Safford. The Eureka shale of Arkansas was referred doubtfully to the Devonian.[2] Dr. Branner thinks the shale belongs to the Lower Carboniferous,[3] because in places it grades into the overlying Lower Carboniferous limestones, and the few fossils that have been found in the shale belong equally to the Devonian and the Lower Carboniferous. The persistency with which such a thin bed occurs unconformably with the Silurian and conformably with Lower Carboniferous beds in the Territory, as well as in Arkansas, also strengthens the theory that it is Lower Carboniferous.

Spavinaw Creek Area.—Exposures of the shale are common around the border of the Silurian area on Spavinaw creek. One of the best exposures seen there was about one mile west of Spavinaw post-office, on the north side of Spavinaw creek. At that point it is about forty feet thick, and is the usual typical, bituminous, rather friable shale.

Illinois River Areas.—On the north side of the Illinois river, west of the Cincinnati-Siloam Springs road, and near the Arkansas-Indian Territory line, good exposures of the shale may be seen. Near the Stewie ford of the Illinois river, along the Cincinnati-Oaks road, the shale outcrops again. In the limited area examined, no complete section was seen, but it appeared to have its usual thickness and characteristics. West of Bunch, at a point about four miles below the mouth of Elk creek, the Eureka shale outcrops in the bed of the Illinois river.

Salisaw Creek Areas.—About two miles northwest of Bunch, along Marble creek, the valley shows the typical Eureka shale soil, but no good exposures of the shale were seen there. Along Walkingstick creek, however, about three and a half miles north of Marble, good exposures of the shale may be seen. At this locality it is about thirty feet thick and contains some calcareous nodules, otherwise it does not vary from its general characteristics. Along Dry creek, one and a half miles northwest of Marble, good exposures of the shale show it to be about thirty feet thick.

[1] *Elementary Geol. of Tenn.*, by James M. Safford and J. B. Killebrew, Nashville, 1885, pp. 112, 118.

[2] *Ann. Rept. Geol. Sur. Ark.*, 1891, Vol. ii, p. 32.

[3] "Phosphate Deposits of Arkansas," *Trans. Am. Inst. Min. Eng.*, *loc. cit.*

Boone Chert and Limestone.

Stratigraphic Position.—Immediately above the Eureka shale, there is a series of cherts and limestones aggregating from fifty to about five hundred feet in thickness, and averaging about three hundred and fifty feet. It was named the Boone chert by Dr. Branner because of its extensive and typical development in Boone county, Ark.[1] These beds are the probable equivalents of the Burlington-Keokuk divisions of the Lower Carboniferous.

Areal Extent.—The Boone chert and limestones form the principal strata outcropping over several counties in southwest Missouri and northwest Arkansas, and continue into the Territory, where they cover half of the Cherokee Nation—three thousand square miles. They lie in the northeastern and east central part of the Cherokee Nation. Roughly, their western limit is four to five miles west of Grand river and their southern limit some twenty to twenty-five miles north of the Arkansas river. Tracing the boundary more definitely, it enters the Territory south of Baxter Springs, Kans., curves to the southwest, passing through Miami, thence bears southward to near Fairland, whence it extends southwestward to a point on the M. K. & T. Railway, some four or five miles southwest of Vinita. From this point it runs southward in a wavy line between the railway and Grand river to a point about fourteen miles north of Ft. Gibson. From this point it runs eastward in a zigzag way to a point about one and a half miles south of Tahlequah. Then in its eastward course it swings southward, passing a little south of Park Hill, makes deep southward swings on the Illinois river, Salisaw and Lee's creeks, and passes into Arkansas a little north of Evansville. All along this border, and more especially its southern part, there are small isolated areas of higher geologic horizons scattered over the chert area along drainage divides.

Structure.—Over most of this area the beds are practically horizontal, but nearer the borders the strata dip toward and at right angles to the border line. In the northwest part of the area this dip, even along the border line, is barely perceptible, but toward the south the dip increases and also becomes more irregular by the increased folding and some faulting along several axes. These disturbances largely account for the irregular border of the chert area on the southwest and south.

[1] *An. Rep. Geol. Sur. Ark.*, 1890, Vol. i, p. 129.

Stratigraphy.—Most of the formation is chert, and the limestone strata are usually confined to the base and top of it. These two limestone horizons are usually five to twenty feet thick each. The limestone interstratified with the chert is in thin layers, seldom more than two or three feet in thickness, and is of rather rare occurrence.

Characteristics of the Chert.—The chert varies in color from white to gray; light gray or white is the prevailing color, and is especially characteristic of the rock that has been exposed to weathering agencies, or is dry. Weathered pieces, however, are often of a brownish color. The rock is almost a uniform mixture of lime and silica, but the proportion of lime and silica varies somewhat at different horizons or even along the same stratum. In weathering it breaks into rather small sharp angular pieces. The strata are usually thin and present a slight wavy and much fractured appearance. These features are doubtless due to the weathering of rock of an uneven composition. These irregularities and characteristics run through the whole chert bed throughout the entire area.

Limestones.—The limestone at the base of the chert bed corresponds to the St. Joe marble of the Geological Survey of Arkansas;[1] it varies from an inch to about thirty feet in thickness; it is of rather uniform texture, quite crystalline, of a rather dark-gray color, and lies in strata from a few inches to four or five feet in thickness. This bed is rarely missing where the base of the Boone chert was seen. On Spavinaw creek and Illinois river it is from fifteen to twenty feet thick. On Dry creek, one and a half miles northwest of Marble, it is about two feet thick, crystalline, gray in color, and contains greenish specks scattered through it.

The limestone that occurs very sparingly through the chert is rarely more than two or three feet thick. It is usually of uniform texture, tough, and of a gray color.

The limestone at the top of the chert is from fifteen to forty feet in thickness. It is massive, tough, gray and crystalline, but in the northwestern part of the area it is arenaceous and somewhat flaggy. This limestone forms the base of a great many small hills along the border of the chert area. It is often marked by glades due to thin soil. Along the west bank of Spring creek, near the south line

[1] *Ann. Rept. Geol. Surv. Ark.*, 1890, Vol. iv, p. 253.

of the Quapaw Nation, hard gray massive beds of the upper Boone limestone are finely exposed in bluffs and benches known as the Devil's Promenade. Along the east bank of the Neosho river, south and southwest of Miami, the upper Boone limestone forms a long outcrop; the bed is composed of shaly, flaggy and lenticular bedded limestone, some of which near the top and especially along parting planes is decidedly arenaceous. Archimedes are abundant in the upper part of these limestones. Along a little brook, one mile to the west of Big Cabin creek, a full section of the limestone overlying the Boone chert is exposed. The limestone bed is about thirty feet thick and arenaceous throughout, though it varies very much in the proportion of sand and lime in different strata. The beds that are most arenaceous are shaly and lenticular and some contain arenaceous limestone nodules with flinty centres. Archimedes occur in some of these strata. East of Grand river, opposite Chouteau, this bed is arenaceous and flaggy. About seven miles east of Adair the Boone limestone outcrops along streams. The rock is massive, hard, gray, fossiliferous limestone. The outcrops seen northeast of Ft. Gibson, west and southwest of Tahlequah, are practically all gray limestone in rather massive strata. The bed as it occurs along the Illinois river and Greenleaf creek southeast of Greenleaf, is about thirty feet thick, mostly gray and massive limestones. There is at the top of the bed, however, a stratum of bluish limestone which weathers to a whitish color, and the base of the bed is somewhat arenaceous, shaly and wavy.

Along Walkingstick creek, about three miles north of Marble, the stratum is thirty feet thick, and is composed of massive gray limestone. The top of this bed, as seen in the base of a hill one and a half miles south of the Tahlequah-Evansville road and four or five miles east-southeast from Wauhillau, has a little blue limestone that weathers white. Near the base it is decidedly arenaceous and shaly; the rest of the bed, which is the greater part of it, is massive gray limestone as usual. East of Stillwell, south and southwest of Westville, the stratum is from thirty to forty feet thick, and is practically all gray limestone in layers from a few inches to five or six feet in thickness.

Fayetteville Shale.

The Fayetteville shale is probably the stratigraphic equivalent of the Warsaw division, as recognized in Illinois, Iowa, etc.

Secs. a–k, Pl. V, show the variation in thickness and the associated strata of the Fayetteville shale along its line of outcrop through the Indian Territory. These sections were made at the following localities:

Sec. a—About two miles west and southwest of Stillwell.

Sec. b—Four or five miles east-southeast from Wauhillau and one and a half miles south of the Evansville-Tahlequah road.

Sec. c—Compiled from sections made northwest of Marble and southwest of Bunch.

Sec. d—West side of Big Vian creek about one and a half miles northwest of Vian.

Sec. e—Compiled from outcrops along the Illinois river and Greenleaf creek, about five miles east-southeast from Greenleaf.

Sec. f—About one mile north of Fourteen Mile creek and one and a half miles northeast of Grand river.

Sec. g—About two and a half miles south-southwest of Markham's store or thirteen miles south of Brushtopped mountain.

Sec. h—One and a half miles east of Grand river, opposite Ned Adair's ferry, east of Chouteau.

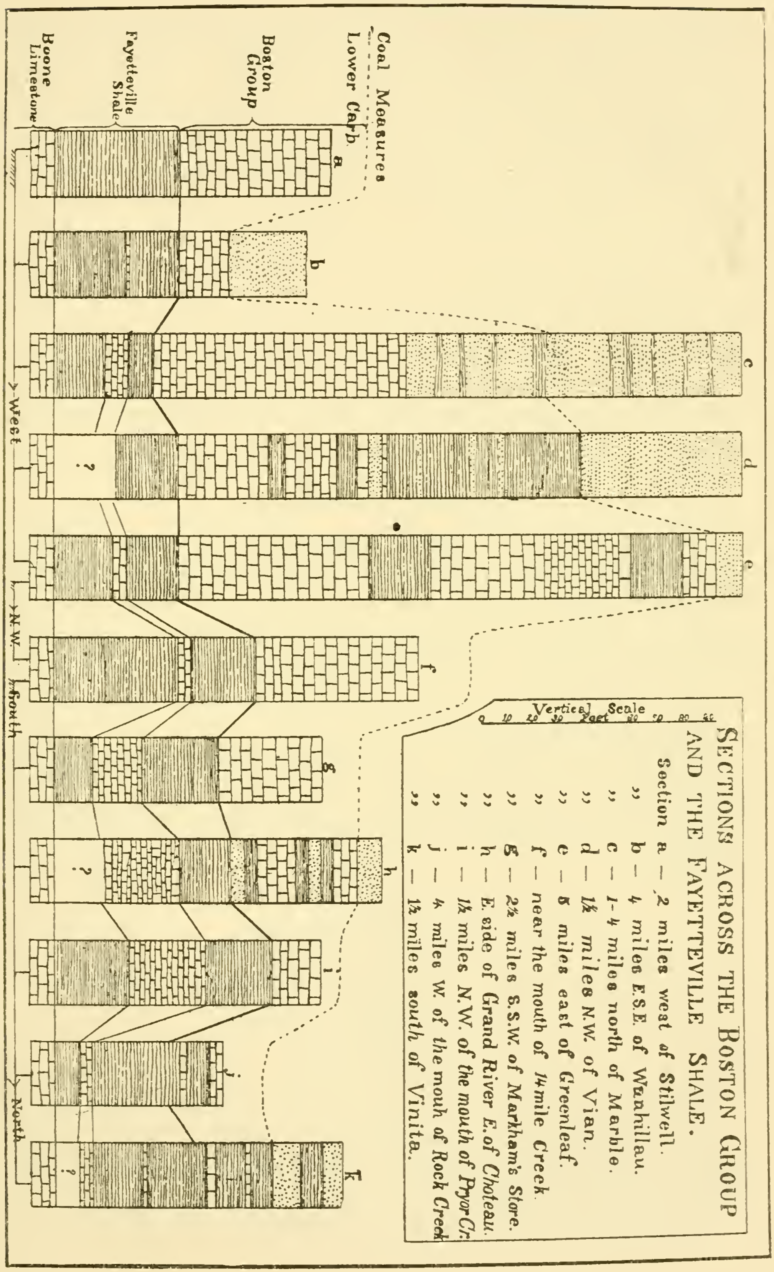
Sec. i—Brushtopped mountain, a small hill one mile north of Pryor creek and one and a half miles west of Grand river.

Sec. j—South side of Rock creek about four miles west of its mouth northeast of Adair.

Sec. k—Along and south of Little Log Cabin creek one and a half miles south of Vinita.

The Fayetteville shale is a black, friable, clay shale, which usually contains clay-ironstone concretions, and has an average thickness of about fifty feet. This shale immediately overlies the upper Boone limestone, and varies but little around the southern and the southwestern border of that limestone, and also along the western border as far north as the Grand river east of Chouteau. Farther to the northward it is more arenaceous and thinner and varies in color from gray to blue and yellowish. It is doubtful whether there are any outcrops as far north as the Indian Territory-Kansas line that may be referred to this shale. The shale is divided throughout by a bed of light blue, friable, fine-grained lime-

Plate V.


Coal Measures
Lower Carb.
Boston Group
Fayetteville Shale
Boone Limestone
a
b
c
d
e
f
g
h
i
j
k
?
West
N.W.
South
North
Vertical Scale
Feet
SECTIONS ACROSS THE BOSTON GROUP AND THE FAYETTEVILLE SHALE.
Section a — 2 miles west of Stilwell.
" b — 4 miles E.S.E. of Webbers Falls.
" c — 1-4 miles north of Marble.
" d — 1½ miles N.W. of Vian.
" e — 5 miles east of Greenleaf.
" f — near the mouth of 14-mile Creek.
" g — 2½ miles S.S.W. of Markham's Store.
" h — E. side of Grand River E. of Choteau.
" i — 1½ miles N.W. of the mouth of Pryor Cr.
" j — 4 miles W. of the mouth of Rock Creek.
" k — 1½ miles south of Vinita.

stone. The lithologic characteristics of this limestone are quite uniform throughout its extent and are such as to contrast it sharply with the limestones of the associated beds. It varies in thickness from an inch to thirty feet. Along Grand river east of Wagoner, Chouteau and Pryor creek, it is twenty to thirty feet thick; farther northward and southeastward it is usually but five to ten feet thick. This bed is apparently confined to the Indian Territory, since it was not observed north of Vinita and was not noted in Arkansas by the Geological Survey of that State. There is, however, a stratum of limestone about a foot thick in the Fayetteville shale three miles southeast of Westville, which from its position and lithologic characteristics, appears to be this bed.

In the Fayetteville shale exposed around the hillsides southwest of Bunch and along Illinois river east of Greenleaf this limestone occurs almost regularly and is usually five or six feet thick.

Batesville Sandstone.

In the isolated small hills northwest, southeast and south of Westville, sandstone beds twenty feet or more in thickness overlie the Fayetteville shale, and are probably the equivalent of the Batesville sandstone. This sandstone bed is apparently lacking at other places over the field where the Fayetteville shale was seen.[1]

Boston Group.

This group is composed of the uppermost beds of the Lower Carboniferous and corresponds to the St. Louis and Chester horizons of Illinois, etc. The classification of the group into beds as was worked out in Washington county, Ark., by Dr. F. W. Simonds[2] is as follows:

Boston group:
- Kessler limestone.
- Coal-bearing shale.
- Pentremital limestone.
- Washington shale and sandstone.
- Archimedes limestone.
- Marshall shale.

These horizons were classified mainly on lithologic characters,

[1] Mr. Stuart Weller has recently shown that the Batesville sandstone is the equivalent of the Aux Vases sandstone of Illinois and Missouri (*Trans. N. Y. Acad. Sci.*, xvi, 251–282).

[2] *Ann. Rept. Geol. Surv., Ark.*, 1888, Vol. iv, p. xiii.

which change rapidly in most of them. These variations are apparently greater in the Indian Territory than they are in Arkansas. In the northern part of the Indian Territory it is doubtful whether the group is represented by any deposits of consequence. It is represented southeast of Vinita by a series of shaly clays and thin beds of impure limestones, aggregating about seventy-five feet in thickness. East of Chouteau, along Grand river, the group is about one hundred feet thick and is rather clearly divided into different beds of limestones and shales. On Salisaw creek and eastward to the Arkansas-Indian Territory line, the group is about one hundred and fifty to two hundred feet thick. The whole group, as outlined in Washington county, Ark., is, however, nowhere in the area studied represented in a characteristic way. The Archimedes and Pentremital limestones are usually together, and it is very doubtful whether the Kessler limestone is at all represented.

This group is usually confined to an escarpment and isolated hills along the western and southern border of the Boone chert and limestone area; at most its outcrop forms a belt only two or three miles wide along the border of the Lower Carboniferous. Secs. a–k, Pl. V, show the development of this group along its line of outcrop from near Stillwell to near Vinita. The hills east, west and south of Stillwell are capped by fifty to seventy-five feet of limestone that belongs to this group. The limestone is usually gray in color, rather massive and in places quite arenaceous. Farther westward, in the isolated hills south of Wauhillau, near the Evansville-Tahlequah road, the limestone and beds of the Boston group are considerably thinner and are overlain by sandstone that is probably Coal Measures. Ten to twenty-five miles south and southwest of Wauhillau, near Bunch, Marble, Vian and along Illinois river east of Greenleaf, the Boston group is one hundred and fifty to two hundred feet thick and probably thicker, since the dividing line that has been used to separate this group from the Coal Measures is largely an arbitrary one and the doubtful beds are mostly classified as Coal Measures. One and a half miles northwest of Marble the lower part of the Boston group beds consists of about one hundred feet of gray limestone slightly interstratified with clay shale and arenaceous shaly limestone. Archimedes occur frequently in the lower part of the limestone bed. Overlying this limestone there is a series of strata aggregating about two hundred feet in thickness, which are composed of sandstones and some interstratified clay shale.

The sandstones vary from massive to flaggy and shaly, and in places near and at the top they grade into a grit. This grit appears to be the equivalent of the so-called Millstone grit of the Geological Survey of Arkansas, since it has the same lithological characteristics and apparently has the same stratigraphic position. It is probable, therefore, that not over one hundred feet of the shales and sandstones overlying the limestones at this place should be referred to the Boston group. The above section (Sec. c, Pl. V), with slight modifications, represents the group as it is shown in outcrops between Bunch and Marble.

The Boston group is well exposed along the west side of Big Vian creek, northwest of Vian, where Sec. d, Pl. V, was made. The section at that place is as follows:

	FEET.
Massive sandstones (Coal Measures ?)	100+
Arenaceous black clay shale	75
Brownish, weathering, hard limestone	½
Shaly sandstone	5
Gray, massive, hard limestone	5
Black clay shale	10
Massive, hard, gray limestone at the base which grades into shaly brownish weathered limestone at the top	15
Clay shale (?)	10
Massive, gray, firm, fossiliferous limestone	35
	135½

The following is a section on the east side of Illinois river, about west-northwest of Marble:

	FEET.
Sandstone and grit (Coal Measures?)	30+
Blue clay shale	5
Uniformly textured, smooth, gray limestone in strata 1 to 2 feet thick	10
Nodular friable limestone in thin, irregular, rough-surfaced strata with clay partings and fillings of lenticular places through the strata	10
Rather uniformly textured, massive, gray, fossiliferous limestone	50
Blue clay shale	20

	FEET.
Hard, gray limestone	2
Sandstone and clay shale	10
Limestone, usually massive, arenaceous, and friable, but it varies to pure, tough limestone of a gray color. Some bluish limestone, which weathers to a white color, occurs near the base of the bed	30
	137

Below this section is about twenty feet of the Fayetteville shale and its included stratum of blue limestone. The limestone at this place is only about two feet thick.

On the west side of Illinois river, about five miles east-southeast from Greenleaf, the following section (Sec. c, Pl. V) may be seen:

	FEET.
Sandstones and grit (Coal Measures?)	at top
Massive, gray, brownish weathering limestone	15
Clay shale	20
Massive gray limestone	4
Blue limestone alternating with a little clay shale. The limestone weathers to a rather smooth but angular wavy surface and a whitish or yellowish color; the weathered cross sections of fossils and wavy branching calcite seams of a darker color than the mass of the rock gives a streaked, wavy and mottled appearance to its surface	30
Rather massive but in part flaggy limestone which in places contains abundant Pentremites	50
Clay shale	25
Gray massive limestone	75
	215

The following section is exposed four miles southeast of Ft. Gibson on the south side of Bayou creek along the Ft. Gibson-Braggs road:

	FEET.
Sandstone (Coal Measures)	at top
Massive gray limestone	10

	FEET.
Argillaceous sandstone, sandstone shale and arenaceous clay shale	20
Limestone: the lower part is brownish weathering and somewhat shaly, the upper part is massive and gray	20
Sandstone	5
Limestone	5
Sandstone	5
Limestone containing Archimedes in the central part of the bed	50
	115
Fayetteville shale and some interstratified blue limestone	at base

West and northwest of Tahlequah, along Pecan creek and Fourteen Mile creek, and along Grand river, east and northeast of Wagoner, the Boston group is usually limited to a fifty to seventy-five foot bed of limestone, which is in places slightly interstratified with clay and contains Archimedes and Pentremites associated throughout almost the entire bed. The Archimedes, however, are more common in the central and lower divisions, while the Pentremites are more common in the central part of the bed. Farther to the north it becomes thinner and more argillaceous until calcareous and arenaceous clays form the principal part of the group as shown in Secs. j and k, Pl. V. East of Pryor creek, Adair, Big Cabin, and south of Vinita, the group is represented by yellowish calcareous clays, friable arenaceous limestones, some hard gray limestone and a little sandstone. The limestone and clays are usually rich in fossils. The following section (Sec. k, Pl. V) will show the general character of the group along its outcrops from the Grand river, east of Chouteau, to within one and a half miles of Vinita.

	FEET.
Brownish weathering massive sandstone (Coal Measures?)	5
Clay shale (Coal Measures?)	10
Sandstone (Coal Measures?)	12
Coal Measures	27

	FEET.
Clay shale which contains some fossiliferous shaly limestone near the base	10
Friable arenaceous fossiliferous limestone	2
Calcareous, fossiliferous, yellowish clays	10
Hard, rough-surfaced, highly fossiliferous limestone	3
Bluish clay shale	25
Limestone	1
	51
Clay shale (Fayetteville shale?)	at base

Fossils of a decided Coal Measures facies were collected from some black clay shale at a place on the M. K. & T. Railway, about four miles north of Vinita. This shale is not more than one hundred and fifty feet above the Boone limestone, so the strata referable to the Boston group, at this place, is probably not more than twenty-five or fifty feet thick.

Between Fairland and Miami the strata that may be referred to this group are gray shales and possibly a little limestone. Northeast of Miami it seems probable that the horizon of the Boston group is overlapped by Coal Measures shales and sandstones, or if this is not the case the group is represented by gray clay shales and some sandstone.

The sections of the Boston group show that it is thicker and apparently has higher beds in the southwestern part of the Lower Carboniferous area where the strata are exposed by being folded or excessively eroded. The same sandstone or grit bed appears to overlie unconformably these different Lower Carboniferous beds at various places. The sandstone beds lying on the Boston group one and a half miles south of Vinita are apparently the same sandstones that rest on the Boone limestone, some six or seven miles southeast of Vinita. Two or three miles southwest from the mouth of Pryor creek a conglomerate sandstone overlies the Boston group to the westward and the Boone limestone to the eastward. The gradual upward change in the Lower Carboniferous deposits from massive and extensive cherts and limestones to shales, arenaceous limestones and sandstones indicate an upward movement of the ocean bottom. This movement may have continued until the deposited beds were subject to slight erosion before the following subsidence began and the sand and grit deposits laid down over them. The continuity of the fauna and the small amount of overlapping in these deposits could, however, allow only a slight break in deposition.

Coal Measures.

The Coal Measures of the Indian Territory and Oklahoma are a direct continuation of the Kansas, the Arkansas and apparently the Texas Coal Measures. The southward extension of the Coal Measures of Kansas enters the Indian Territory in a belt sixty-five miles wide, which extends from about ten miles west of the northeast corner of the Territory to near the northwest corner. The western limit of this belt through the Territory bears about 10° west of south throughout the area studied. The eastern limit running southward from the Kansas-Indian Territory line extends south 40° W. for a distance of forty miles, then runs nearly south for fifty miles and then with a gentle southward curve and zigzag line extends eastward into Arkansas. The belt through the Territory, therefore, at first contracts from the eastern side for a distance of nearly one hundred miles, then rapidly widens on the eastern side so that the Coal Measures in the territory studied, roughly covers an L-shaped area. The southward continuation of the Coal Measures into Texas is broken in the southern part of the Indian Territory by the overlapping of Cretaceous deposits.

Structure.—The Coal Measures lie in the three structural and topographic groups previously mentioned. The horizontally uplifted plateau, or Ozark type, includes the larger part of the Coal Measures lying between the southern boundary of the Lower Carboniferous area and the northern boundary of the Arkansas river valley. The area of the folded beds, or Ouachita type of structure, lies principally south of the Arkansas river and east of a line connecting the mouth of the Canadian river, Brooken, and a point about seven miles west of McAlester. The remaining and by far greater part of the Coal Measures in the area under discussion belongs to the Prairie Plains region, and consists of gently westward and northwestward dipping strata.

Stratigraphy.—With the possible exception of slight uncomformities produced by overlapping of the basal beds of the Lower Coal Measures, there seems to be no break in the stratigraphy from Lower

Carboniferous into Permian beds. A rough estimate gives a total thickness of 25,000 feet for the Coal Measures deposits. Most of these strata were laid down near shore and are, therefore, subject to the irregularities of near-shore deposits. Arenaceous clay shales, sandstones, limestones, coal, grits and conglomerates occur in relative abundance in the order named. Well-marked beds that may be used for making stratigraphic divisions are for the most part wanting. The limestone beds are mainly confined to the northern part of the field and to the central part of the Upper Coal Measures. The shale and the sandstone beds are so local and repeated in such lithological uniformity that they serve poorly for divisions; fossils, especially in the southern part of the field, are of rare occurrence. The larger coal beds, with some irregularities, extend across the entire field and furnish the best means of grouping the formations. The workable beds of coal are all confined to the lower part of the Upper Coal Measures. The Coal Measures deposits will be considered under the following classification :

Coal Measures.	Upper Coal Measures.	Poteau group.[1]
		Cavaniol group.[1]
	Lower Coal Measures.	

Plates II and VII show the relation of these groups.

The Lower Coal Measures produce no coal; the Cavaniol group contains the workable beds, and the Poteau group contains some thin ones.

Lower Coal Measures.

There are three different areas of the Lower Coal Measures in this field. One lies in the southeastern part of the region, and is bounded on the north by a line running along the southern base of the Poteau mountains and the north side of Fourche Melane valley and Jack Fork mountains; from the latter place the bounding line runs southwesterly and passes out of the field. This area includes the Fourche Melane valley and the upper part of the Kiamichi valley and Walker, Black Fork, Rich, Blue, Windingstair, Jack Fork and Kiamichi mountains and the intervening areas.

[1] These names were taken from the names of mountains in the southeastern part of the field where the beds included in those groups are well represented.

The second area is a strip about four miles wide and twenty-two or twenty-three miles long which extends into the Territory along the Backbone anticline. The third one is an irregular belt bordering the Lower Carboniferous on the south and west. The most of the southern part of this belt lies near and to the north of the Arkansas river, and includes the Boston mountains; the western part of the belt extends along the Missouri, Kansas and Texas railway from Wagoner to Vinita, and from Vinita it runs northeasterly, passing into Kansas at and southwest of Baxter Springs. Along the Arkansas-Indian Territory line this belt is about twenty miles wide, but it gradually narrows to the westward and northwestward until north of Wagoner it is usually but four to five miles wide.

Lithology of the Lower Coal Measures.—Throughout this group there is such a constant repetition of arenaceous gray, clay shales and sandstones of uniform character that the lithology and stratigraphy are exceedingly monotonous.

There is, however, some marked variation introduced by the grits and conglomerates at the base of the group north of the Arkansas river, and by the limestones south of Ponola, Wilburton and Hartshorne. Some minor variations in color and composition also occur in the shales and sandstones. The sandstones are usually massive, but in places they are flaggy or shaly and micaceous, argillaceous, calcareous, ferruginous, or bituminous. A little quartzite occurs in the Windingstair mountains and some conglomerates may be seen in the vicinity of Thomasville.

Thickness of the Lower Coal Measures.—The greatest thickness observed in the Lower Coal Measures was in the southeastern part of the field. In this locality the strata throughout show little variation; extensive faults lie along the north side of Walker, Black Fork, Windingstair and Kiamichi mountains, and smaller faults at other places; and overthrows occur at some places to further complicate the interpretation of the stratigraphy. On account of these difficulties, as well as the limited amount of work the reconnaissance would allow, only rough estimates of the thickness of the exposed beds will be attempted.

The longest continuous section studied in this part of the field was from the base of the Poteau mountains to the south side of Rich mountains. This section extends north and south about three or four miles west of the Arkansas-Indian Territory line. The stratigraphy somewhat generalized along this line is shown in

Sec. 8 (p. 366.) The strata exposed along this section are divided into three divisions by two faulted areas. The division on the north is about seven thousand feet thick, the one next further to the south is about eleven thousand feet thick, but possibly contains as much as six thousand feet of strata that is repeated from the first division, thus leaving only five thousand feet to be added to the seven thousand of the first division, which gives twelve thousand feet. The third and last division is about fifteen thousand feet thick. In this the heavy sandstone beds in the south side of Black Fork and Rich mountains are each about one thousand feet thick, and are so much more massive than any of those exposed to the north, that they are probably lower horizons. There is a strong probability, however, that the strata of Black Fork and Rich mountains are the same, which is the case if the beds are overthrown to the north, as they appear to be. If this is the case, only five thousand feet of the thickness of the strata of the two mountains, should be added to the section already estimated. The remaining five thousand feet of strata to the north of Black Fork mountain is most likely a repetition of the strata exposed and counted farther to the northward. So only five thousand feet more can safely be added to the twelve thousand feet, which gives a total thickness of seventeen thousand feet.

It is possible that this section represents a thickness of as much as twenty-five thousand feet of strata, but under the observed conditions, seventeen thousand feet seems more probable, and even that may be too much. The base of the formation was not seen, but as the thickness exposed is very nearly as much as the estimated thickness of the whole formation in Arkansas,[1] it is probable that almost the total thickness of the beds is exposed in this section. The Lower Coal Measures in Arkansas, however, run a little higher in the section than they do in the Indian Territory, since the Huntington Coal belongs to a higher horizon than the coals farther to the east in Arkansas.[2]

Stratigraphy of the Lower Coal Measures.—The basal beds of the Lower Coal Measures appear to be exposed only in the Cherokee Nation. Overlying the Lower Carboniferous there is a series of sandstones, grits and shales which belong to the basal beds of

[1] Dr. Branner estimates the thickness of these Lower Coal Measures in Arkansas to be 18,480 feet thick (*Amer. Jour. Sci.*, Vol. ii, September, 1896, p. 235)

[2] *Geol. Surv. of Ark.*, Ann. Rep., 1888, Vol. iii.

the Coal Measures. No definite division between the Lower Carboniferous and the Coal Measures could be fixed, but the fossils found in the highest strata, known to belong to the Boston group, are a mingling of species belonging to the highest Lower Carboniferous and the Coal Measures. These sandstones, grits and shales have the same lithological characteristics and stratigraphic position as the so-called Millstone grit of the Geological Survey of Arkansas.[1] There is every gradation from the smooth, fine-grained sandstones to the grits and coarse conglomerates. Good examples of the grit may be seen, north of Camp Track, five miles south of Bunch, in places three to four miles northwest of Vian, and along the east side of Illinois river west-northwest from Marble. This grit is composed of angular grains of quartz, which are usually from one to two millimetres in diameter, but occasionally are from five to six millimetres in diameter. Hematite usually forms the cementing matter for the grit. The basal group of the Lower Coal Measures in the Cherokee Nation is composed mainly of sandstones and grits throughout. No section was made of this group along the Arkansas-Indian Territory line, but it is probably not less than two thousand feet thick. Five to ten miles southeast of Ft. Gibson it is three hundred feet thick; from eight to ten miles northeast of Ft. Gibson it is about two hundred feet thick. From this place further to the north it rapidly thins until from about ten miles north of Wagoner to near Baxter Springs, Kans., it is but five to fifteen or twenty feet thick. In this northern part of the field the grit is usually lacking and the sandstones are very variable. These basal sandstones cap the isolated hills and east-facing escarpments from four to six miles south of Chouteau, one and a half miles south of Vinita, three miles west of Afton, one mile south of Miami, and about two miles south of Baxter Springs, Kans. There is a bed of gray, arenaceous clay shale two hundred and fifty to three hundred feet thick overlying this group of sandstones and grits throughout the Cherokee Nation. This shale is somewhat thicker in the northern part of the field than it is toward the south. It comprises nearly all the Lower Coal Measures strata that lie west of Grand and Spring rivers and throughout that area it is marked by level or gently undulating prairie plains.

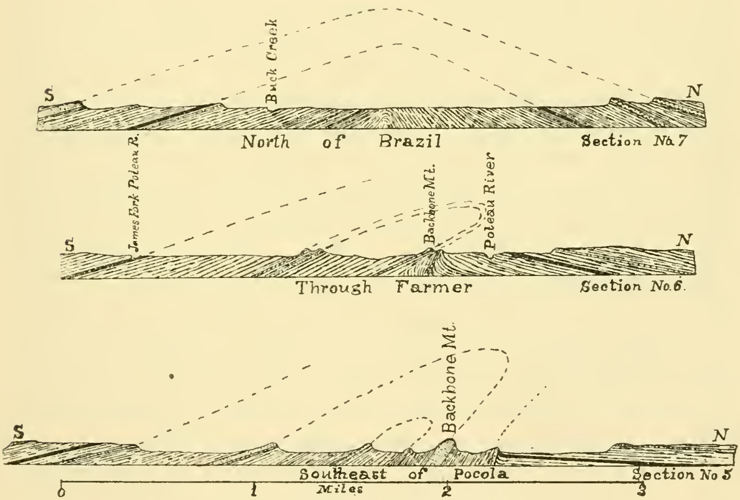
The southern extension of the Lower Coal Measures area of the Cherokee Nation outcrops along the Milton-Bokoshe anticline

[1] *Ibid.*, Vol. iv, p. 106, and 1890, Vol. i, pp. 113–115.

south of the Arkansas river. The rocks exposed along this anticline are mainly sandy clay shales north of Bokoshe, and massive and flaggy sandstones east and west of Milton. The sandstones one mile south of Bokoshe are highly micaceous and often smooth-surfaced flags. About two thousand feet of Lower Coal Measures rocks are exposed on either side of the anticline in this locality.

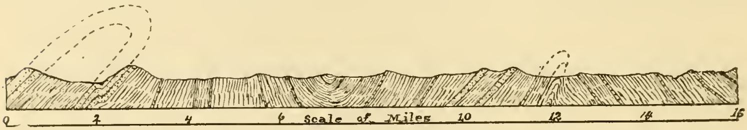
In the Backbone mountain area of the Lower Coal Measures the beds are massive sandstones and thick gray arenaceous clay shales. The sandstone beds are from about thirty to five hundred feet in thickness and the interbedded shales are from eight hundred to thirteen hundred feet in thickness. The structure of the Backbone ridges that best account for the observed facts is shown in Secs. 5, 6 and 7, Pl. VI and in Pl. I. This overthrown anticline is faulted

Plate VI.



Sections across the Backbone anticline.

along the north side of the overthrow. The faulting runs westward from Arkansas almost to the western end of the mountains, where it ends rather suddenly. With the gradual lessening of the faulting toward the west the strata on the north side of the fault line increase in dip as they approach the axes of the anticlinal folds. The thickness of strata exposed in this area, on either side of the anticline, is a little over twenty-five hundred feet. The Lower Coal Measures in the southeastern part of the field show very little variation lithologically from the beds described to the northward; there is, however, a great increase in the thickness of the deposits. The east and west folding in this area has made it possible to get moderately long exposures of the same strata along the axial direc-



Sec. No. 8. Across the Lower Coal Measures, south of Poteau mountain.

tion of the folds. The three groups of strata shown in Sec. 8 are, with modifications, extended to the westward the full length of the area. The faulting along the north side of Walker mountains, along Fourche Melane valley and south of Hartshorne, separates the group on the north from the Central or Walker mountain group. The central and southern groups are in part repetitions of the same strata. The second group comprises the strata of Walker mountains, Blue mountains and nearly all the strata lying between Bengal and Hartshorne. The beds between Hartshorne and Bengal are referred to the second division rather doubtfully, since this necessitates an upthrow of about six thousand feet along the faulted belt south of Hartshorne and along Fourche Melane valley. Such a throw would require the strata in a block about one and three-quarter miles wide to be tilted at an angle of 45° to the south. South of Hartshorne, as shown in Sec. 10, the strata are tilted at angles of 40° to 50° for a distance of about two miles and possibly farther. This tilting is only slightly offset on the north side of the fault line by gentle dips of 4° to 5°. So it seems probable that the throw is as much as six thousand feet at this place. South of Wilburton and southwest of Red Oak the strata on the south side of the Fourche Melane valley do not dip very much more steeply than they do on the north side, and as the dips are in opposite directions the beds appear to be the same. They are, however, not the same, for the coal beds are not repeated on the south side of the valley. Furthermore, the strata are different lithologically, since limestones occur on the south side and may be traced westward to the limestone beds south of Hartshorne, which beds have been shown to probably belong six thousand or seven thousand feet below the

Grady coal bed. The third division comprises the strata of Black Fork, Rich and Windingstair mountains.

The highest bed of the Lower Coal Measures is a sandstone about one hundred and fifty feet thick, although varying in thickness from a few inches to three hundred feet. Mr. H. M. Chance calls it the Tobucksy[1] sandstone. This bed is especially important because it immediately underlies the Grady coal bed and makes a ridge

Sec. No. 9. Across the Winding Stair and the Kiamichi mountains, south of Hanson creek.

of considerable prominence almost all along its line of outcrops, so that the coal may be closely located by tracing the outcrop of this sandstone. It has an unusual persistence for a sandstone, outcropping as it does almost regularly over an area of one thousand square miles, and forming an unbroken ridge excepting at a few places where streams have cut across it, from about three miles northwest of Heavener to Hartshorne. This ridge is a very prominent topographic feature rising usually one hundred to three hundred feet above the surrounding country. South and southwest of Heavener and southwest and west of Milton, this bed is thick and makes ridges from one hundred to three hundred feet high. Where it is thick enough to make a prominent topographic feature it is shown so on the sketch map. The following are approximate sections of the upper part of the Lower Coal Measures as they occur in Secs. 8 and 5; the sections were made south and southeast of Heavener and across the Backbone anticline.

	SEC. 8. FEET.	SEC. 5. FEET.
Sandstone	200	50
Gray arenaceous clay shale	1000	1150
Massive sandstone	50	250
Gray arenaceous clay shale	660	600
Sandstone	30	35
Clay shale	1150	500

[1] *Trans. Am. Inst. Min. Eng.*, Vol. xviii, p. 659.

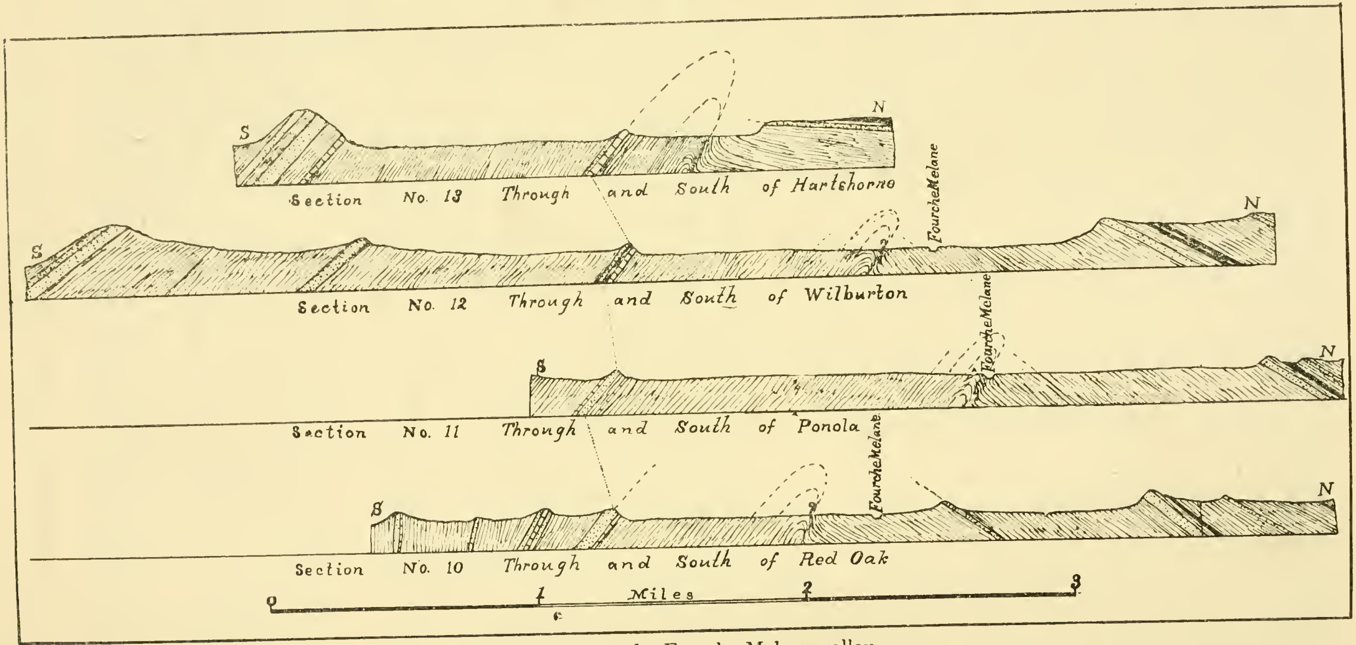
SEC. 8.	FEET.
Sandstone	10
Shale and thin beds of sandstone	800
Sandstone	10
Shale and thin beds of sandstone	800
Sandstone	10
Shale and thin beds of sandstone	2000

The beds that appear to underlie these are those of Walker, Blue and Jack Fork mountains.

They are but little different lithologically from the beds above them, but the shales are of a darker color, and in the western part of the belt there is some limestone to break the usual monotony. The main ridges of Walker, Blue and Jack Fork mountains have sandstones from fifty to one hundred feet or more in thickness in the southern part of the ridges.

Secs. 10, 11, 12 and 13, Pl. VII, show the general character and variation of the rocks on the south side of Fourche Melane valley from a point south of Red Oak to a point south of Hartshorne. Sec. 10 lies south of Red Oak. The limestone, calcareous sandstone and arenaceous limestone shown in this section were seen southwest of Red Oak, but they probably extend farther to the east. In this section the first sandstone bed south of Fourche Melane is about one hundred feet thick, usually massive. Twenty to thirty feet of arenaceous limestone and calcareous sandstone occurs on the north side, or at the base of this sandstone bed. The next ridge to the south is formed by two sandstones each ten to fifty feet thick and separated by about fifty feet of clay shale. This shale southwest of Red Oak is partly replaced by five to ten feet of hard, rather nodular, blue limestone. On the north side of the fourth sandstone—the third prominent ridge south of Fourche Melane—there is more arenaceous limestone and calcareous sandstone. It is only five to ten feet thick at the places where it was seen. Farther west or south of Ponola, Sec. 11 shows the stratigraphy of the first ridge south of Fourche Melane. At this place the strata dip south 50°. There is a hard, blue limestone, fifteen to twenty feet thick, on the south side of the ridge; this limestone is underlain by about one hundred and twenty-five feet of sandstone, of which the upper fifty feet is ferruginous and fossiliferous, and the lower part is hard massive sandstone. This sand-

Plate VII.



Sections across the Fourche Melane valley.

stone is underlain by alternating strata of shaly sandstones and arenaceous clay shale, which in turn is underlain by thirty feet of gray fossiliferous limestone.

Farther west, south of Wilburton, only one limestone bed was seen, but others are probably covered by débris. A somewhat generalized section at this point is shown in Sec. 12. Farther to the west the limestone beds increase rapidly in thickness, until south of Hartshorne the lowest one is about one hundred and fifty feet thick.

Strata of Black Fork, Rich and Windingstair Mountains.—Massive sandstones with regular texture and smooth bedding planes and dark gray clay shales are the prevailing rocks of these mountains. The sandstones in the southern part of Black Fork mountain are about one thousand feet thick, principally massive, and light in color; some flaggy and shaly beds occur near the centre of the section. The sandstones of the south side of Rich mountain appear to be about one thousand feet thick and closely resemble those of Black Fork mountain, but are seemingly somewhat more flaggy and have a little more interbedded clay shale. The strata in the valley between the two mountains and those in the north side of both mountains are principally arenaceous clay shale and thin beds of sandstone. Along Big creek on the north side of Black Fork mountain, the sandstones and shales are distributed in the proportion of about one of sandstone to five of shale. The sandstones are usually from four to eight feet thick and have irregular bedding planes. About one mile east of Page a massive sandstone about fifty feet thick is broken across by a fault and so impregnated with bitumen that the rock has a very black color. There is a small anticline immediately southwest of this point in Big creek.

These irregularities seem to be only local breaks and crumplings on the side of a very large fold. Windingstair mountains appear to be the westward continuation structurally and stratigraphically of Black Fork and Rich mountains. Sec. 9 shows in a general way the stratigraphy of the Windingstair mountains south of Hanson creek. The north side of the mountains at this point is steep and rather free from ridges or cañons running parallel to the range, while the southern slope is broken by a number of ridges running parallel to the main mountain and less elevated toward the south. Deep erosion channels lie between some of these ridges and connect with a cross channel leading into the Kiamichi valley to the south.

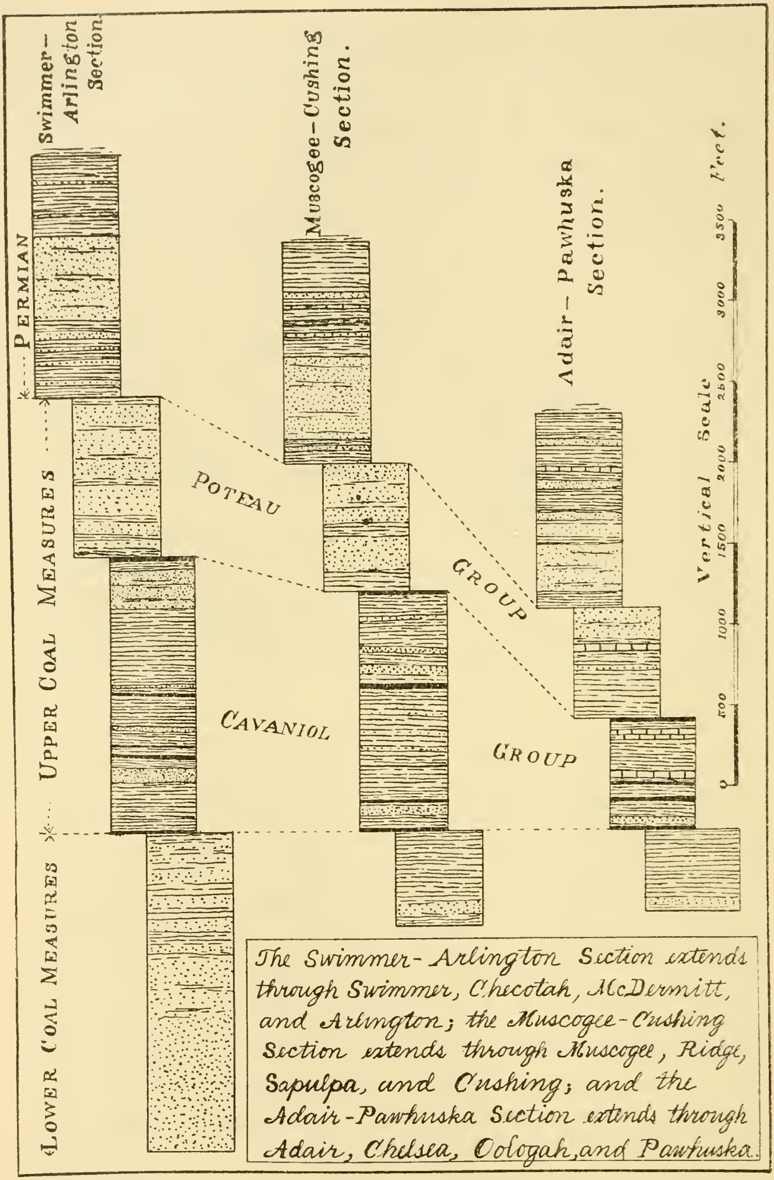
Evidences of faulting and sharp folding may be seen on either side of the mountain along this section, and almost all through the mountain along the St. Louis and San Francisco railway. These orographic movements have metamorphosed the rock locally until the sandstones are quartzites and the shales are hardened. Some limestone concretions and boulders occur in the shales on the north side of the mountain west of the head of Hanson creek and along the railroad four or five miles southeast of Bengal. Occasional chert concretions occur with the limestones. Porous, ferruginous sandstones were found in a number of places on the north face of the mountains and they were usually found to be fossiliferous. The rocks of Kiamichi valley southeast of Talihina appear to be principally dark gray clay shale. Some of this shale that was taken from a well dug at the south side of Windingstair mountain, about ten miles east of Talihina, was almost black and so crushed that every piece showed "slickensides."

The strata of the northern side of Kiamichi mountains bear a close resemblance to and are possibly to be correlated with the massive sandstones of Black Fork mountain, Rich mountain and Windingstair mountain. Sec. 9 shows the structure and approximate stratigraphy of the Kiamichi mountains at the point where they were studied.

Upper Coal Measures.

Cavaniol Group.—This part of the Coal Measures is confined to the area outlined on the map between the outcrops of the lowest and the highest workable coal beds. From Arkansas this coal-bearing belt extends westward into the Territory for a distance of about sixty-five miles and divides into two belts, one of which extends northward and the other southwestward. The belt extending westward from Arkansas lies mainly to the south of Arkansas river and has an average width of about forty miles. The belt extending northward passes through the Creek and Cherokee Nations into Kansas, and has an average width of about twenty-five miles. It lies mainly on the west side of the Missouri, Kansas and Texas railway. The southwest belt extends through the western part of the Choctaw Nation, and has, in the area studied, an average width of about fifteen miles. That part of the Cavaniol group lying to the south and east of Canadian river will be referred

Plate VIII.



Comparative sections of the Coal Measures. Compiled from cross-sections through the Cherokee, Creek and Osage Nations.

to as the Choctaw coal field,[1] since this term has been applied to that area by Dr. H. M. Chance.

Stratigraphy.—The beds of this group consist of shales, sandstones, coals and limestones. The shales comprise the larger part of the strata, but sandstones are very abundant, especially in the southern part of the field, while limestone beds are confined to the northern part. The workable coals are thicker in the southern region, but extend throughout the entire area. The group is thickest in the southeastern part of the field and thinnest in the northern part. The decrease in thickness appears to run regularly to the westward and northward. The most constant and easily recognizable horizons in this division are the coal beds. Three of these are thick enough over most of the field to work. Other thin beds occur locally, and one in particular that lies about one hundred feet above the central coal bed extends almost regularly throughout the field where its horizon occurs. The lowest workable coal varies in thickness from one and a half to six feet; this is the coal that Dr. H. M. Chance named the Grady coal.[2] It proves to be, without any reasonable doubt, the same bed as the one worked at Huntington, Jenny Lind, Hackett and several other places in Arkansas.

The next higher workable coal is the McAlester bed, which varies in thickness from about one and a half to four feet. The highest workable bed is the Mayberry coal, which also varies in thickness from one and a half to four feet. These three coal beds apparently extend throughout the entire area of the Cavaniol group, but north of the Canadian river there are four coal beds that are worked locally. These four beds were not studied in enough detail to correlate them throughout. The outcrops and stratigraphy noted in different sections across the group give some suggestions of correlation, as may be seen in Pls. I and VIII.

The following table shows a rough estimate of the distance between the coal beds at different places in the Choctaw coal field:

[1] *Trans. Am. Inst. Min. Eng.*, Vol. xviii, p. 653.

[2] *Ibid.*, 1890, Vol. xviii, pp. 1, 2.

Vertical Distance between the Grady and McAlester Coal Beds.

LOCALITIES.	FEET.
One mile east of Fanshaw	2500
Two miles east of Red Oak	2500
West of Cameron	2000
North of Brazil	2000
South of Milton	2000
North of Wild Horse Prairie	1300
East of Krebs	1000

Vertical Distance between the McAlester and Mayberry Coal Beds.

LOCALITIES.	FEET.
Cavaniol mountains	3000
Northeast end of Sans Bois mountains	2200
West end of Sans Bois prairie	1500

These estimates show a marked tendency throughout the whole division to decrease in thickness towards the west and northwest.

The following sections will show the general stratigraphy of the two lower coal beds and the intervening strata in the Choctaw coal fields:

	One mi. west Fanshaw.	West of Cameron.	South side of Buck Creek Prairie.	North side of Buck Creek Prairie.	Northwest of Wild Horse Prairie.
	FEET.	FEET.	FEET.	FEET.	FEET.
Coal	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$		$1\frac{1}{2}$
Shale		1200			
Sandstone		10			
Shale	200	100	200	200	300
Sandstone	25	10	200	25	50
Shale	2000	300	600	900	400
Sandstone	50	25	15	25	100
Shale	300	400	1000	1000	500
Coal	3	3	4	4	3

Two sandstones and three clay shale beds usually form the sequence of strata between the two lower workable coals. This prevailing condition is shown in the above sections. This usual sequence, however, is not constant, for in some places, as northwest of Alderson, only one sandstone intervenes, and in other places, such as west of Cameron, there are three. This table is not intended to show a strict correlation but rather a comparison.

The strata between the McAlester and Mayberry coal beds apparently are more diversified. In the Cavaniol mountains four thick sandstone beds alternating with clay shales intervene between the coals. Northwest of San Bois there are three intervening sandstones, while to the west of Sans Bois two sandstone beds intervene, and east of Brooken only one of prominence lies between the two coal seams. This shows a decrease in the number and thickness of intervening beds to the northwest. The intervening sandstone beds, especially those in Cavaniol and Sans Bois mountains, are usually from fifty to two hundred feet thick and are evenly textured strata that usually have smooth bedding planes, and vary from flaggy to massive sandstone. The first sandstone below the Mayberry coal is especially flaggy and smooth where it was seen on the east end and north side of Cavaniol mountain. The dark gray clay shales interstratified with these sandstones are from two hundred to five hundred feet thick. South of the Arkansas river a coal seam four to eight inches thick occurs almost regularly one hundred feet above the McAlester coal.

A rough estimate of the thickness and stratigraphy of the Cavaniol group north of the Canadian river, along a line running from McDermitt through Checotah and Starvilla to the mouth of the Canadian river, is as follows:

	FEET.	INCHES.
Coal	2	6
Gray, arenaceous clay shale	50	
Friable, shaly and massive sandstone and some clay shale	300	
Gray, arenaceous clay shale	500	
Sandstone	10	
Clay shale	25	
Coal		10
Clay shale	200	
Sandstone	25	
Clay shale	100	
Coal		8
Clay shale	50	
Coal	1	3
Clay shale	50	
Sandstone and some interstratified clay shale	100	
Clay shale	300	
Coal	1	6
Total thickness (approximate)	1700	

A section across the group along a line from Muscogee, through Ridge and Sapulpa to Cushing, is approximately as follows:

	Feet.	Inches.
1. Coal (Mayberry coal?)	2	
2. Clay shale	100	
3. Sandstone	10	
4. Shale	50	
5. Thin strata of light gray, arenaceous, limestone and calcareous sandstone interstratified with gray calcareous clay shale	25	
6. Gray clay shale	100	
7. Friable, black, carbonaceous, clay shale, which contains near the top some limestone nodules one and a half feet in diameter. These limestone nodules are carbonaceous and black, but weather to a white color and contain numerous calcite seams running through the nodules	50	
8. Sandstone	25	
9. Clay shale	100	
10. Sandstone	50	
11. Clay shale	100	
12. Coal	1	6
13. Gray, arenaceous clay shale containing some thin sandstone strata which are ferruginous in places	500	
14. Coal		4
15. Clay shale	250	
16. Coal	1	
17. Clay shale	100	
18. Sandstone	25	
19. Clay shale	25	
20. Coal (Grady coal?)		8
Total thickness (approximate)	1500	

A section across the group along a line from Adair through Chelsea and Oologah to Pawhuska is as follows:

		Feet.
1.	Coal (Maybery coal?)	2
2.	Clay shale	100
3.	Limestone (Oologah limestone[1])	50
4.	Arenaceous clay shale and a little interstratified shaly sandstone	200
5.	Gray limestone	15
6.	Clay shale	5
7.	Coal	1¼
8.	Clay shale and sandstone	50
9.	Limestone	2
10.	Clay shale	50
11.	Coal	1½
12.	Clay shale and a little sandstone	150
13.	Sandstone	25
14.	Clay shale	15
15.	Coal (Grady coal?)	1½
	Total thickness (approximate)	650

These three sections show the Cavaniol group to have the following northward variations: A regular decrease in the thickness of the group and in the relative proportion of sandstones; a gradual increase in the limestones, and a very little variation in the coals. The most marked stratigraphic feature introduced in the northern part of this group is the limestone beds.

Bed 5 of the Muscogee–Cushing section is apparently the Oologah limestone, since it has about the same stratigraphic position and shows the decrease of limestone common to the southward development of the beds. At and in the vicinity of Oologah this limestone is massive, hard, gray, rather unevenly textured, and in places contains gray chert nodules. On weathering, the limestone breaks into irregular-shaped pieces. This bed forms an east-facing escarpment fifty to one hundred feet high along the west side of Verdigris river valley east of Oologah. The limestone bed next in

[1] This bed has been called the Oologah limestone because it is finely exposed in Oologah, along Four Mile creek at the west edge of Oologah, and in an escarpment some three miles to the east of that place.

importance to the Oologah limestone is Bed 5 of the Adair-Pawhuska section. This limestone is beautifully exposed in bluffs along the east bank of Verdigris river, quarter of a mile below the McClellan ford east of Talala. At that place it contains no chert nodules, but in other lithologic characteristics it closely resembles the Oologah limestone.

Poteau Group.—Dr. J. P. Smith was the first to introduce the name Poteau in connection with strata included in this group.[1] It is probable that the Poteau mountain beds do not extend so high as the base of the Permian, but the name "Poteau group" will be applied to the group of beds between the Cavaniol group and the base of the Permian, as outlined in this paper. The dividing line used to separate the Poteau group from the Permian is merely an arbitrary one, and is, in the main, based on the fossils found at different localities. The beds of the Poteau group lie in small isolated areas and in a long belt-like area. The isolated areas are the upper parts of Poteau, Sugar Loaf, Cavaniol, Sans Bois, Tucker Knob and McChar mountains. The long belt-like area lies on the west side of the Cavaniol group throughout the field and has an average width of fifteen to twenty miles. The beds of this area are tilted to the northwest, where they lie against the western limit of the folded region of the Choctaw coal field, but further to the north the beds dip gently to the westward or a little north of westward. Throughout this belt the outcropping hard rock beds form east and southeast facing escarpments.

The Mayberry coal bed was not definitely located in either the Sugar Loaf or the Poteau mountains, but as these mountains do not appear to be situated in quite such deep synclines as the Cavaniol or the Sans Bois mountains the coal must be at a somewhat higher elevation. All four of these mountains are nearly the same in elevation—between twenty-five hundred and three thousand feet. From fifteen hundred to two thousand feet of the upper part of the Cavaniol and Sans Bois mountains belong to the Poteau group and twelve hundred to fifteen hundred feet of the tops of Sugar Loaf and Poteau mountains belong to this group. The group northwest of McAlester is about two thousand feet thick, but probably the top beds represent somewhat higher horizons than the top

[1] *Jour. Geol.*, Vol. ii, pp. 194-196, and *Proc. Amer. Phil. Soc.*. Vol. xxxv, No. 152, p. 17.

beds of the above-named mountains, since the same strata decrease in thickness to the westward and especially to the northward. This group, in the main, consists of arenaceous gray clay shales and massive sandstone beds, but in the northern region limestone beds are included in the group. The sandstone beds of this group are somewhat more massive than they are in the Cavaniol group, as is shown in Plate VIII. In the southeastern region nearly all the sandstones are massive, but southwest of Enterprise they are frequently ripple-marked and thin-bedded. Three miles south of South Canadian, sandstones form a prominent escarpment about one hundred feet high. This sandstone is composed of strata that are usually massive, but sometimes flaggy, so that beautiful smooth flags of varying thickness are common. Five or six miles farther to the west, the dark-gray clay shale overlying this bed contains some black carbonaceous fossiliferous limestone nodules. The shales along Salt creek five miles east of Calvin are light gray, very arenaceous, and carry some thin shaly layers of calcareous sandstone that are quite fossiliferous. The sandstone beds, so prominent a feature of this group in the southeast and southern region, gradually grow less prominent to the northward, but as far north as McDermitt they are the prevailing strata. A section across this group in the vicinity of Sapulpa is as follows:

	FEET.
1. Massive and slightly friable sandstones and a little interbedded clays and shales........	400
2. Clay shale............................	100
3. Massive, rather friable sandstones..........	200
4. Gray clay shale, calcareous in places, and containing two feet of limestone about one hundred and fifty feet from the base of the bed..................................	100

A section across this group west of Oologah shows the following sequence of strata:

	FEET.
1. Sandstones interbedded throughout with arenaceous clay shale........................	200
2. Fossiliferous shaly limestone..............	3
3. Clay shales and shaly sandstone............	50
4. Hard, massive, gray limestone.............	25

		FEET.
5.	Clay shale	25
6.	Arenaceous limestone	5
7.	Sandstone	5
8.	Clay shale containing calcareous nodules and some fossils	25
9.	Gray clay shale, blackened in places by carbonaceous matter often calcareous and occasionally containing thin shaly sandstone strata	300
	Total thickness (approximate)	650

Bed 4 of the above section forms the bed-rock of Bird creek about twelve miles from Skiatook along the Skiatook-Pawhuska road. From that point to the eastward it gradually rises until it forms bluffs on either side of the creek and farther eastward forms an east-facing escarpment.

This escarpment was seen about due west of Oologah and two to three miles west of the Osage-Cherokee Nation boundary line. The limestone bed is very massive, gray in color, unevenly textured, rather highly crystalline and contains little ferruginous masses scattered throughout most of the bed.

Origin of the Sediments of the Coal Measures.—Throughout the Coal Measures the thickness of the sediments gradually decreases northward and westward. The most rapid decrease is toward the north, and the lower beds decrease more rapidly than the higher ones. The Lower Coal Measures decrease from a thickness of about seventeen thousand feet in the southern part of the field to a thickness of five hundred to six hundred feet in the northern part. The Upper Coal Measures across the same field decrease from about seventy-five hundred to twelve hundred feet.

The Permian beds, so far as they were studied, show very little, if any, decrease in thickness toward the north. This continuous northward thinning of the beds in the central and northern part of the field is shown in Pl. VIII. The relative proportion in the amount of shales and limestones to sandstones and conglomerates gradually increases westward and especially northward. Because of these conditions the sediments are considered to have come from a land area lying to the southeast.

Permian.

The Permian area studied lies along the western part of the field and extends into it twenty to forty miles. Only about fifteen hundred feet of Permian sediments are included in the area studied. The base of the Permian deposits, as it is defined in the present paper, begins with the first appearance of Permian species, and not with the disappearance of the Coal Measures fauna, for that usually predominates even to the highest beds studied. The strata of the Permian beds consist of massive sandstones, clay shales, conglomerates and limestones. The clay shales are mostly gray and arenaceous, but toward the top they grade through blue to reddish and red shales and marls. The lower two hundred to one thousand feet is composed of alternating clay shale and sandstone beds in about the proportion of one hundred feet of shale to ten of sandstone. These beds are overlain by two hundred and fifty to five hundred feet of sandstones and conglomerates, and these in turn are overlain by bluish and red clay shales and marls which are interstratified with occasional thin sandstones and limestones. Four generalized sections, at widely separated localities, were made across these Permian beds. The first section extends in a northwest direction from Calvin to a point west of Wewoka near the western boundary line of the Seminole Nation. This section will be referred to as the Calvin-Wewoka section. The other three sections, with their localities, are shown in Pl. VIII.

The following table gives the generalized stratigraphy of these four sections:

		Feet.
Calvin-Wewoka Section.....	Red and blue clay shales and marls interstratified with thin sandstone and very rare limestone beds.....	250+
	Conglomerate and sandstone.....................	250
	Gray and blue clay shales interstratified with thin sandstone...............	600
	? Massive yellowish weathering friable sandstone	400

Swimmer-Arlington Section.	Red and blue clay shales and marls interstratified with thin sandstone and scarcer limestone beds.........	250+
	Sandstone and conglomerate	500
	Gray arenaceous clay shale beds alternating with sandstone beds in about the proportion of ten of shale to one of sandstone	500
Muscogee-Cushing Section..	Red and blue clay shales and marls interstratified with thin sandstone beds and more rarely thin limestone beds.............	250+
	Alternating blue and gray clay shales and sandstones	200
	Sandstone and a little clay shale..................	500
	Gray clay shales and a few thin sandstone beds.....	100
Adair-Pawhuska Section....	Blue and red clay shales and marls alternating with thin sandstone and a few thin limestone beds.	500+
	Sandstone and a little clay shale..................	500
	Alternating beds of gray clay shale and thin sandstones.................	200

In general terms, the section farthest to the south, or the Calvin-Wewoka section, shows two thick sandstone groups of beds with an intervening and an overlying clay shale. The other three sections show one principal group of sandstone beds overlain and underlain by clay shales. It may be possible, however, that the lower sandstone group of the Calvin-Wewoka section belongs to the Poteau group, as seems to be the case judging from lithological evidence. If this be true, there are three generalized groups running through the entire area. The following descriptions of local developments and their general connections will give a better idea of the stratigraphy and lithology.

About five miles northwest of Calvin, along Sandy creek, the strata consist of massive, friable, yellowish sandstones interstratified with gray and yellowish argillaceous compact sand. About a mile farther west, along the Calvin-Wewoka road, there are some sandstone beds exposed which are practically like the above, but are highly fossiliferous and apparently belong either to the Upper Coal Measures, or the Lower Permian. These sandstones are so friable, thick and extensive that the country for fifteen miles or more to the northwest of Calvin is covered by deep loose sand from the disintegration of the rock. Railway cuts three to four miles northwest of Holdenville show the strata at that place to be principally gray arenaceous clays with occasional reddish bands and streaks which carry numerous yellowish, ferruginous, calcareous clay nodules. There is some lenticular interbedded sandstone which is hard and has a clear quartzitic appearance. Similar clay shales and thin interstratified sandstone beds, aggregating a thickness of six hundred feet or more, are the outcropping strata for several miles on either side of Holdenville. It seems probable that this group is the base of the Permian and is the stratigraphic equivalent of about five hundred feet of similar strata outcropping both east and west of McDermitt. Farther to the north it thins quite rapidly or is replaced by sandstone beds until west of Kelleyville and northwest of Skiatook it is but one hundred to two hundred feet thick and contains no red clays. At the top of this group, along the Calvin-Wewoka section, there is a limestone from three to four feet thick. This limestone outcrops about two miles southwest of Wewoka, where it shows a weathered surface of gray and yellowish color, is very friable, and in places is quite arenaceous. About a mile farther west this limestone is overlain by a conglomerate and sandstone bed aggregating two hundred and fifty feet or more in thickness. The larger part of this bed at this locality is conglomerate, composed of rather angular light-colored chert pebbles two to three millimetres in diameter, imbedded in a sand matrix. Occasional well-rounded quartz pebbles, about five millimetres in diameter, also occur in the conglomerate. This conglomerate has the same lithologic characteristics of the conglomerate beds that extend from northern to central Texas through the Cisco division of the Coal Measures of Texas.[1] The outcrop of this conglomerate and sandstone bed forms a belt ten miles wide that extends nearly north and south through the centre of the Seminole Nation. Farther northward the conglomerate gradually disappears and the beds thicken by addition of other sandstone beds until it is apparently five hundred feet thick and outcrops in a belt about twenty miles wide. This belt lies twelve miles east of Arlington, two miles west of Kelleyville, and about eight or ten miles east of Pawhuska.

The sandstones of this belt are so friable that the country is covered by loose sand derived from the disintegrated rock. About fourteen miles east of Arlington the group contains a bed of light-gray sandy clay shale, seventy-five or one hundred feet thick, which contains some limonite nodules and one thin stratum of rich hematite. There are also two strata of limestone, each one or two feet thick, which occur near the base and top of the shales respectively.

Proceeding upward and westward across this sandstone and conglomerate group of beds from about a mile west of Kelleyville to about eight miles west of that place, the strata are found to be mainly sandstones, which are massive, rather ferruginous, friable and weather into rough irregular shapes. The rapid disintegration of the rock covers the ground with deep loose sand. About nine miles west of Kelleyville the sandstone is slightly shaly in places and some red sandy clays are interstratified with the sandstone beds. The dip of these beds is about fifty feet per mile to the westward, or a little north of westward. The thin interbedded shales and clays and alternating harder sandstone beds allow only very slight escarpments to be formed. On top of these sandstones there is about one hundred feet of gray sandy clay shale and some interstratified shaly sandstone. Over the outcrop of this shale there is not much loose sand and the bed is marked by little prairies. The dip of the strata here is about twenty- to twenty-five feet per mile to the westward. Ten to eleven miles west of Kelleyville the rocks are massive cross-bedded sandstones; in these the bedding planes are curved surfaces separating their lenticular and wedge-shaped layers. It is interstratified with a little bluish argillaceous sand, red clays and gray argillaceous sandy shale. For the next five or six miles to the westward the strata lie practically horizontal, then farther west to the top of the sandstone group,

[1] *Geol. Surv. Texas*, Fourth An. Rep., 1892, pp. 372, 445; *Geol. Surv. Texas*, Second An. Rep., 1890, pp. 362, 495, 509, and Pl. xvi.

which is about two miles west of Polecat creek, sixteen miles east of Cushing, the strata apparently dip about twenty-five feet per mile. The top of this group outcrops along the bed of Bird creek, one mile west of Pawhuska. On either side of the creek, beds of gray and bluish clay shales and some thin sandstone beds overlie the main sandstone group, so that it does not form the chief outcrops until a point about ten miles southeast of Pawhuska is reached.

From Pawhuska the rocks of this group outcrop southeastward along the Skiatook-Pawhuska road for about fifteen miles. The principal variation across this Adair-Pawhuska section is a slight increase of argillaceous strata. A three-foot bed of brownish weathering arenaceous limestone occurs about one and a half miles east of the road crossing Birch creek. From Birch creek westward the dip of the strata appears to be twenty-five to thirty feet per mile to the westward, while for five or six miles to the east the strata are almost horizontal.

The next higher group of Permian beds consists of bluish and red clay shales and marls, interstratified at rather wide intervals with thin cross-bedded sandstones and occasional thin limestones. The following local developments will give the usual characteristics. The lower part of this group, as seen eight to nine miles west-southwest from Wewoka, consists of sandy clay shales, bluish and reddish colored, and massive sandstones that have edges and parts of the rock broken into thin shaly wedge-shaped, cross-bedded strata. The sandstone is either light grayish or reddish-colored. The gray sandstone is coarse textured. Farther westward and higher geologically the sandstones decrease in quantity and most of the strata are red clay shales.

Two and a half miles southeast of Econtuska there is a little white, nodular, arenaceous limestone interstratified with yellowish marls. The strata at Bellmont and between that place and Arlington are mainly red arenaceous, calcareous clays interstratified with occasional red sandstones which are usually rather massive, but often broken into shaly and flaggy parts by cross-bedding planes. Some of the sandstone has a light gray-color. There are also rare beds of arenaceous and even quite pure fossiliferous limestone which varies in color from white and gray to red and almost invariably weathers to rough nodular fragments. One of these beds outcrops one mile west of Arlington. Five or six miles east of Arlington there is a one to three-foot bed of hard crystalline red limestone which is overlain by a thin clay bed, and this in turn by sandstone conglomerate similar to that west of Wewoka.

The limestone that outcrops one mile west of Arlington is probably the same as the one that occurs sixteen miles east of Cushing and two miles west of Pawhuska. Dr. J. P. Smith called the limestone bed that outcrops from two to three miles west of Pawhuska, the Pawhuska limestone.[1]

The limestone bed that outcrops about sixteen miles east of Cushing is from four to six feet thick, gray, bedded in rough, thin layers, and contains *Fusulina* and crinoids. The strata here lie almost horizontal, and the same bed outcrops ten miles east of Cushing along the Kelleyville-Cushing road. About five miles east of Cushing higher beds of massive friable cross-bedded sandstone, red clay, and arenaceous limestone outcrop. Some of the limestone is quite pure, but usually it occurs in nodular form in beds one-half to one foot thick. In the vicinity of Cushing clay shales and marls are the principal strata. Six miles north-northwest from Cushing along the south or east bank of the Cimarron river there is a bluff about fifty feet high showing massive and shaly sandstones of light gray or yellowish and reddish color, sometimes cross-bedded. A little rough concretionary limestone occurs at the top of the bed. The twin peaks from ten to eleven miles north of Cushing are composed of red clays capped by concretionary limestone. Some of the limestone contains chert. The Pawhuska limestone outcrops about twelve miles north of Cushing along branches of Salt creek. The bed at this locality is about five feet thick, gray in color, hard, rough surfaced, unevenly textured and rich in two species of *Fusulina*.

The following section was compiled from outcrops of strata found five to ten miles south of Pawnee.

	FEET.
1. Red clays	at top.
2. Limestone	1½
3. Red, bluish and gray clays	150
4. Limestone (Pawnee limestone)[2]	2
5. Principally gray clay shales	100
6. Pawhuska limestone	5

[1] *Jour. Geol.*, Vol. ii, p. 199.

[2] Stratum 4 appears to be the same as the bed of limestone outcropping on the east side of the courthouse grounds at Pawnee, and for convenience it will be called the Pawnee limestone.

The Pawnee limestone outcrop on the east side of the courthouse grounds at Pawnee consists of three to four feet of hard evenly textured, tough, bluish gray limestone underlain by five to six feet of yellowish blue marls. Both the limestone and marls are rich in fossils. The Pawhuska limestone bed which outcrops in the bed of a creek half a mile northeast of Pawnee at an elevation of about one hundred feet below the Pawnee limestone, is, at this place, about five feet thick; the lower three feet is hard and massive, while the upper part of the bed is friable. *Fusulinæ* are very abundant in this bed.

Four miles south of Ralston in the banks of Coal creek there is a three to five-inch bed of coal which appears to be below the Pawnee limestone. The following section was compiled from exposures of an escarpment facing the Arkansas river valley at a point about two miles southeast of Ralston.

	FEET.
1. Light gray and yellowish weathering sandstone	15
2. Gray clay shale	4
3. Nodular gray limestone (Pawnee limestone ?).	3
4. Red clays and light gray shaly sandstones	100
5. Pawhuska (?) limestone	5

The Pawhuska limestone outcrops along the Gray Horse-Pawhuska road at every creek crossing for seven to eight miles from Gray Horse, and also about five miles southwest of Pawhuska. At the latter place it is about ten feet thick, unevenly textured, gray in color, and underlain by yellowish and bluish clays. A section of the strata in the vicinity of Pawhuska is about as follows:

	FEET.
1. Blue and red clays	at top.
2. Pawhuska limestone	10
3. Clay shale	50
4. Sandstone	50
5. Clay shale	150
6. Sandstones	at base.

This limestone outcrop forms a little escarpment facing east and running north about two miles west of Pawhuska, while the first sandstone bed below the limestone cap the buttes and escarpments around the village.

General Classification of Rocks of the Indian Territory.[1]

System.	Series.	Group.	Correlations.	Beds.	Maximum Thickness in Feet.
	Permian.		Albany division, Texas. Neosho and Chase formations, Kansas.	Shales, sandstones, conglomerates and limestones.	1,500
Carboniferous	Coal Measures	Poteau.	Wabaunsee and Cottonwood formations, Kansas Cisco division, Texas.	Massive and shaly sandstones and shales.	2,000
		Cavaniol.	Missouri formation, Kansas.	Shales, sandstones and coals	5,500
		Lower Coal M.	Strawn, Milsap and Canyon divisions, Texas	Shales, sandstones.	17,000
	Lower Carboniferous.	Boston.	St. Louis.	Limestones, shales and sandstones.	200
				Batesville sandstone.	25
		Osage.	Osage.	Fayetteville shale.	50
				Boone chert and limestone.	500
				Eureka shale.	50
		Kinderhook.		Wanting.	
Devonian.	Devonian.			Wanting.	
Silurian.	Upper Silurian		Niagara, New York. St. Clair Marble, Arkansas.	Marble and saccharoidal sandstone.	75+
	Lower Silurian			Saccharoidal sandstone, chert and dolomitic sandstones and limestones.	200+

[1] Since this paper was put in type Mr. Stuart Weller has definitely correlated the Batesville sandstone of these tables with the Aux Vases sandstone of Illinois. His results show that the hitherto tentative correlations of these Arkansas and Indian Territory rocks require more careful paleontologic study.—*Trans N. Y. Acad. Sci.*, xvi, 251–282.

PART II.

Paleontology.

The fossils collected from various localities over the field are listed in locality groups, and arranged in their stratigraphic order. All the species listed here and the originals figured are deposited in the geological museum of Stanford University.

Lower Carboniferous.

Upper Boone Limestone (Burlington–Keokuk).—Collections of fossils from the upper Boone limestone were made at three different localities. At the north side of West monntain, three miles southeast of Westville, the following fauna was found :

1. *Productus scabriculus* ? Martin.
2. *Productus cherokeeensis* n. sp. Drake.
3. *Productus* (*Marginifera*) *adairensis* n. sp. Drake.
4. *Productus ovatus* Hall.
5. *Athyris* (*Seminula*) *subquadrata* Hall.
6. *Rhynchonella grosvenori* White.
7. *Spirifer keokuk* Hall.
8. *Eumetria vera* Hall.
9. *Rhynchonella mutata* ? White.
10. *Discina* sp.?
11. *Archimedes* sp.?

Seven miles east of Adair the upper Boone limestone contains the following fauna :

1. *Productus* (*Marginifera*) *adairensis* n. sp. Drake.
2. *Productus ovatus* Hall.
3. *Productus longispinus* ? Sowerby.
4. *Productus* sp.?
5. *Derbya kaskaskiensis* McChesney.
6. *Spirifer keokuk* Hall.
7. *Athyris* (*Seminula*) *subquadrata* Hall.
8. *Orthothetes crenistria* Phillips.
9. *Myalina* sp.?
10. *Archimedes* sp.?

The following fossils were collected from outcrops of the upper Boone limestone found along Ballard's creek one mile west of Echo :

1. *Orthothetes crenistria* Phillips.
2. *Productus cestriensis* Worthen.
3. *Orthis swallovi* Hall.
4. *Eumetria vera* Hall.
5. *Athyris* sp.?
6. *Archimedes* sp.?
7. *Phillipsia* sp.?

Fayetteville Shale (Warsaw).—No fossils were collected from the shale itself, but the limestone bed that occurs near the centre of the shale bed is very fossiliferous in places. One and a half miles south of Vinita *Productus cestriensis* Worthen is a very common fossil in this limestone. East of Chouteau on either side of Grand River valley, opposite Ned Adair's ferry, the following fauna was collected from this limestone :

1. *Productus ovatus* Hall.
2. *Productus cherokeeensis* n. sp. Drake.
3. *Productus alternatus* N. and P.
4. *Productus* sp.?
5. *Productella* sp.?
6. *Athyris* (*Seminula*) *subquadrata* Hall.
7. *Athyris* sp.?
8. *Spirifer keokuk* Hall.
9. *Spirifer trigonalis* Martin.
10. *Rhynchonella* (*Camarophoria*) *cooperensis* Shumard.
11. *Chonetes planumbona* M. and W.
12. *Pentremites godoni* de France.
13. *Pleurotomaria taggerti* Meek.
14. *Pleurotomaria* sp.?
15. *Platyceras* sp.?
16. *Edmondia burlingtonensis* White and Whitfield.
17. *Edmondia ellipsis* White and Whitfield.

Boston Group (St. Louis–Chester).—A very good representative fauna of this group was collected at four different localities. Most of the fossils came from the Archimedes and Pentremital horizons. The following fauna was found in this group east of Grand river, opposite Wagoner, about one and a half miles northeast of the mouth of Fourteen Mile creek.

1. *Productus ovatus* Hall.
2. *Productus cestriensis* Worthen.
3. *Productella* sp.?
4. *Spirifer* sp.?
5. *Terebratula bovidens* Morton.
6. *Athyris* (*Seminula*) *subquadrata* Hall.
7. *Athyris* sp.?
8. *Camarophoria wortheni* Hall.
9. *Eumetria verneuilana* Hall.
10. *Eumetria vera* Hall.
11. *Aviculopecten simplex* ? Dawson.
12. *Posidonomya fracta*? Meek.
13. *Edmondia* sp.?
14. *Pentremites godoni* de France.
15. *Archimèdes communis* Ulrich.
16. *Archimedes swallovana* Hall.
17. *Archimedes terebreformis* Ulrich.
18. *Archimedes* sp.?
19. *Zaphrentis spinulifera* Hall.
20. *Phillipsia* sp.?

The following fauna was collected from this group five miles east of Adair.

1. *Productus* (*Marginifera*) *adairensis* n. sp. Drake.
2. *Productus cherokeeensis* n. sp. Drake.
3. *Productus cestriensis* ? Worthen.
4. *Productus pertenuis* ? Meek.
5. *Productella* sp.?
6. *Chonetes loganensis* ? Hall.
7. *Orthis dubia* Hall.
8. *Orthothetes crenistria* Phillips.
9. *Spiriferina kentuckensis* Shumard.
10. *Rhynchonella grosvenori* White.
11. *Eumetria verneuilana* Hall.
12. *Spirifer keokuk* Hall.
13. *Athyris* (*Seminula*) *subquadrata* Hall.
14. *Phillipsia scitula* M. and W.

Seven or eight miles southeast of Big Cabin the following collection was made:

1. *Productus cherokeeensis* n. sp. Drake.
2. *Productella* sp.?
3. *Athyris* (*Seminula*) *subquadrata* Hall.
4. *Spiriferina kentuckensis* Shumard.
5. *Rhynchonella grosvenori* White.
6. *Eumetria vera* Hall.
7. *Chonetes* sp.?
8. *Archimedes* sp.?
9. *Zaphrentis* sp.

The Boston group contains the following fauna one and a half miles south of Vinita:

1. *Productus cherokeeensis* n. sp. Drake.
2. *Productus cora* ? d'Orbigny.
3. *Athyris* (*Seminula*) *subquadrata* Hall.
4. *Chonetes planumbona* ? M. and W.
5. *Spiriferina kentuckensis* Shumard.
6. *Spirifer keokuk* Hall.
7. *Straparollus lens* ? Hall.
8. *Zaphrentis lanceolata* ? Worthen.
9. *Archimedes proutanus* M. and W.
10. *Michelinia eugeneæ* White.
11. *Orthoceras* sp.?
12. *Bellerophon* sp.?
13. *Pleurotomaria* sp.?

Coal Measures.

LOWER COAL MEASURES.

The Lower Coal Measures are very poor in fossils, and collections of any special value were made at only three different localities:

Along the limestone bed and ridge two and a half miles south of Ponola and Wilburton.

1. *Productus longispinus* ? Sowerby.
2. *Productus cora* ? d'Orbigny.
3. *Derbya crassa* ? M. and W.
4. *Rhynchonella illinoisensis* Worthen.

5. *Athyris* sp.?
6. *Spiriferina* ? *kentuckensis* Shumard.
7. *Retzia* ?
8. *Spirifer* sp.?
9. *Spirifer rockymontanus* Marcou.
10. *Septopora* ?
11. *Playtyceras* sp.?

One mile south of Muscogee the following fossils were found in shaly and friable limestones and arenaceous clay shales:

1. *Productus pertenuis* ? Meek.
2. *Productus splendens* N. and H.
3. *Productus longispinus* Sowerby.
4. *Spirifer lineatus* Martin.
5. *Spirifer rockymontanus* Marcou.
6. *Spirifer* sp.?
7. *Derbya crassa* M. and P.
8. *Discina convexa* Shumard.
9. *Athyris* (*Seminula*) *subtilita* Hall.
10. *Septopora biserialis* Swallow.
11. *Zaphrentis* sp.?

Four miles north of Vinita, where the M. K. & T. railway crosses a brook, the following fauna was collected from some black shale:

1. *Productus pertenuis* ? Meek.
2. *Spirifer cameratus* Morton.
3. *Athyris* (*Seminula*) *subtilita* Hall.
4. *Derbya crassa* Meek and Hayden.
5. *Chonetes* sp.?
6. *Belleropon* sp.?

UPPER COAL MEASURES.

Cavaniol Group.—This group is represented in the collection of fossils from five different localities as follows:

The following fossils were found in a ferruginous sandstone one hundred and fifty feet above the Grady coal and four miles northwest of Hackett, Ark.

1. *Derbya crassa* M. and H.
2. *Nuculana bellistriata* Stevens.
3. *Bellerophon carbonarius* Cox.
4. *Aviculopecten occidentalis* Shumard.

One and a half miles west of Starvilla along a little branch some shaly argillaceous limestone contains great numbers of *Productus pertenuis* ? Meek, and *Discina nitida* Phillips occurs rarely. In some ferruginous sandstone, six miles southwest of Salisaw on the east side of Big Salisaw creek, the following fauna was collected :

1. *Productus cora* d'Orbigny.
2. *Terebratula bovidens* Morton.
3. *Athyris* (*Seminula*) *subtilita* Hall.
4. *Spirifer rockymontanus* Marcou.
5. *Retzia* (*Hustedia*) *mormoni* Marcou.
6. *Derbya crassa* M. and H.
7. *Aviculopecten occidentalis* Shumard.

The following fauna was collected from the Oologah limestone in the western part of the town of that name :

1. *Productus semireticulatus* Martin.
2. *Athyris* (*Seminula*) *subtilita* Hall.
3. *Chonetes* sp. ?
4. *Syringopora* sp. ?

The following fossils were found in the limestone bed that outcrops along Verdigris river a quarter of a mile below the McClellan ford, which is about four miles east of Talala. This limestone belongs about two hundred feet below the Oologah limestone :

1. *Productus punctatus* Martin.
2. *Productus semireticulatus* Martin.
3. *Productus* (*Marginifera*) *splendens* N. and P.
4. *Productus pertenuis* ? Meek.
5. *Spirifer cameratus* Morton.
6. *Spirifer lineatus* Martin.
7. *Spiriferina kentuckensis* Shumard.
8. *Athyris* (*Seminula*) *subtilita* Hall.
9. *Chonetes mesoloba* N. and P.
10. *Chonetes* sp. ?
11. *Fusulina cylindrica* Fischer.

Poteau Group Fauna.—Collections of fossils were made at four different localities in this group. The shales immediately overlying the Mayberry coal bed at the coal mines, four miles northwest of Poteau, contain the following fauna :

1. *Discina nitida* Phillips.
2. *Aviculopecten rectilaterarius* Cox.
3. *Aviculopecten dubertianus* Dawson.
4. *Nuculana bellistriata* Stevens.
5. *Nucula ventricosa* Hall.
6. *Bellerophon carbonarius* Cox.
7. *Gastrioceras globulosum* ? Meek and Worthen.

Six miles southwest of South Canadian some limestone nodules included in a clay shale bed contain the following fossils:

1. *Nucula ventricosa* Hall.
2. *Pleurotomaria sphærulata* Conrad.
3. *Bellerophon crassus* Meek and Worthen.

Five or six miles northwest of Calvin, the following fauna occurs in friable sandstones:

1. *Productus semireticulatus* Martin.
2. *Productus pertenuis* ? Meek.
3. *Strophalosia* ? *spondyliformis* White and St. John.
4. *Schizodus wheeleri* Swallow.
5. *Nuculana bellistriata* Stevens.
6. *Murchisonia* sp. ?
7. *Pinna peracuta* Shumard.
8. *Aviculopecten catactus* ? Meek.[1]
9. *Gastrioceras globulosum* Meek and Worthen.

Ten miles south of Okmulgee, about one hundred and fifty feet above the base of the Poteau group, the following fossils were found in sandstone:

1. *Aviculopecten occidentalis* Shumard.
2. *Solenopsis solenoides* Geinitz.
3. *Pleurophorus angulatus* Meek and Worthen.

The following fossils were collected west of Oologah, about two miles west of the Cherokee-Osage Nation boundary line:

1. *Productus splendens* N. and P.
2. *Spirifer cameratus* Morton.
3. *Spirifer lineatus* Martin.
4. *Athyris (Seminula) subtilita* Hall.
5. *Spiriferena kentuckensis* Shumard.

6. *Meekella striatocostata* Cox.
7. *Temnocheilus forbesianus* McChesney.
8. *Chonetes* sp. ?

Near the top of the group, at a place about ten miles northwest of Skiatook, the following fauna was found in sandstone strata :

1. *Chonetes verneuilana* N. and P.
2. *Chonetes laevis* Keyes.
3. *Productus* sp. ?
4. *Sanguinolites* sp. ?

Permian Fauna.

Good collections of fossils were made at three different places from beds that are classed as the lowest Permian. The first two lists given below afford the evidence that has been used to draw the line between the Permian and the Coal Measures. These two collections of fossils come from widely separated localities and apparently from the same stratigraphic position.

Five miles east of McDermitt along the McDermitt-Chelsea road the following fauna was found in beds of sandstone.

1. *Productus semireticulatus* Martin.
2. *Productus nebrascensis* Owen.
3. *Productus auriculatus* Swallow.
4. *Orthis* sp. ?
5. *Derbya crassa* Meek and Hayden.
6. *Nuculana bellistriata* Stevens.
7. *Pinna peracuta* Shumard.
8. *Aviculopecten occidentalis* Shumard.
9. *Aviculopecten* sp. ?
10. *Myalina swallovi* McChesney.
11. *Edmondia aspenwallensis* Meek.
12. *Edmondia reflexa* Meek.
13. *Schizodus wheeleri* Swallow.
14. *Schizodus insignis* nov. sp. Drake.
15. *Macrodon obsoletus* Meek.
16. *Macrodon carbonarius* Cox.
17. *Bakevellia parva* ? M. and H.
18. *Murchisonia marcouiana.*
19. *Gervilia ohioensis* Herrick.

20. *Pleurophorus angulatus* Meek and Worthen.
21. *Pleurophorus* sp. ?
22. *Pleurotomaria* sp. ?
23. *Pseudomonotis hawni* Meek and Hayden.

Four miles west of Sapulpa and about one-half of a mile north of the Sapulpa-Kelleyville road the following fauna was collected.

1. *Productus cora*? d'Orbigny.
2. *Derbya crassa* Meek and Hayden.
3. *Chonetes verneuilana* Norwood and Pratten.
4. *Chonetes lævis* Keyes.
5. *Myalina swallovi* McChesney.
6. *Nucula bellistriata* Stevens.
7. *Edmondia nebrascensis* Geinitz.
8. *Dentalium meekianum* Geinitz.
9. *Solenopsis solenoides* Geinitz.
10. *Yoldia subscitula* Meek and Hayden.
11. *Schizodus wheeleri* Swallow.
12. *Pseudomonotis hawni*? Meek and Hayden.
13. *Pleurophorus angulatus* Meek and Worthen.
14. *Pleurophorus* sp. ?
15. *Pleurophorus* sp. ?
16. *Pleurotomaria sphærulata*? Conrad.
17. *Murchisoma* sp. ?
18. *Bellerophon carbonarius* Cox.

Three or four miles west of McDermitt, and about one mile west and northwest of the Pigler place, there are some highly fossiliferous sandstones. These beds are three hundred or four hundred feet above the base of the beds containing the fossils of the above two lists. Fossils were collected from two different sandstone beds in these higher horizons four miles west of McDermitt. The lower sandstone bed contains the following fossils:

1. *Productus nebrascensis* Owen.
2. *Productus auriculatus* Swallow.
3. *Pinna peracuta*? Shumard.
4. *Myalina swallovi* McChesney.
5. *Aviculopecten occidentalis* Shumard.
6. *Pleurotomaria* sp. ?

The upper fossiliferous sandstone bed lies about fifty to seventy-five feet higher and contains the following fauna:

1. *Productus semireticulatus* Martin.
2. *Productus nebrascensis* Owen.
3. *Productus pertenuis* Meek.
4. *Productus auriculatus* Swallow.
5. *Derbya crassa* Meek and Hayden.
6. *Athyris* sp.?
7. *Orthis resupinoides*? Cox.
8. *Edmondia gibbosa* Swallow.
9. *Pinna peracuta* Shumard.
10. *Myalina swallovi* McChesney.
11. *Myalina recurvirostris*? Meek and Worthen.
12. *Myalina subquadrata* Shumard.
13. *Schizodus wheeleri* Swallow.
14. *Schizodus curtus*? Meek and Worthen.
15. *Bakevellia parva*? Meek and Hayden.
16. *Dentalium meekianum* Geinitz.
17. *Monopteria gibbosa* Meek and Worthen.
18. *Aviculopecten occidentalis* Shumard.
19. *Nucula bellistriata* Stevens.
20. *Pseudomonotis hawni* Meek and Hayden.
21. *Gervillia ohioensis* Herrick.
22. *Loxonema cerithiforme*? Meek and Worthen.
23. *Avicula* sp.?
24. *Avicula* sp.
25. *Pleurophorus* sp.
26. *Sanguinolites*?

The Seminole sandstone and conglomerate beds that run northward through the Territory are, as a rule, barren of fossils, and no collections of importance were made in them.

Pawnee and Pawhuska Beds.—Collections of fossils from these beds were made at ten different localities. These fossils were collected from strata that apparently extend from the base of the Pawhuska limestone to a horizon three hundred or four hundred feet above that limestone. The first five lists of fossils come from strata that appear to belong to the Pawhuska limestone. One to four miles southwest of Arlington the following fossils were found in a limestone bed.

1. *Productus* (*Marginifera*) *splendens* Norwood and Pratten.
2. *Spirifer cameratus* Morton.
3. *Chonetes verneuilana* Norwood and Pratten.
4. *Allorisma subcuneatum* Meek and Hayden.
5. *Pinna peracuta* ? Shumard.

The following fauna was found in what appears to be the Pawhuska limestone, along branches of Salt Creek twelve miles north of Cushing.

1. *Spirifer cameratus* Morton.
2. *Spirifer planoconvexus* Shumard.
3. *Athyris* sp. ?
4. *Schizodus wheeleri* Swallow.
5. *Zaphrentis* sp.
6. *Fusulina cylindrica* Fischer.
7. *Fusulina gracilis* ? Meek.

About ten to fifteen feet above this limestone, at a place eleven miles south of Pawnee, the following fossils were collected :

1. *Productus cora* d'Orbigny.
2. *Chonetes granulifera* Owen.
3. *Spirifer cameratus* Morton.
4. *Athyris sultilita* Hall.
5. *Myalina subquadrata* Shumard.
6. *Bellerophon percarinatus* Conrad.

The following fossils were found in the limestone bed outcropping in the bed of the creek at the road crossing one-half mile northeast of Pawnee courthouse.

1. *Productus* (*Marginifera*) *splendens* Norwood and Pratten.
2. *Chonetes granulifera* Owen.
3. *Chonetes lævis* Keyes.
4. *Rhynchonella* (*Pugnax*) *uta* Marcou.
5. *Spirifer cameratus* Morton.
6. *Athyris* (*Seminula*) *subtilita* Hall.
7. *Fusulina cylindrica* Fischer.

The following fauna was found in the Pawhuska limestone at a place about four and one-half miles southwest of Pawhuska.

1. *Productus semireticulatus* Martin.

2. *Productus cora* d'Orbigny.
3. *Athyris* (*Seminula*) *subtilita* Hall.
4. *Spirifer cameratus* Morton.
5. *Spirifer planoconvexus* Shumard.
6. *Chonetes* sp. ?
7. *Lophophyllum proliferum* Hall.
8. *Pleurotomaria illinoisensis* Worthen.

The following fossils were collected from a friable limestone bed that occurs about one hundred and fifty feet above the Pawhuska limestone, at a place five miles east of Cushing.

1. *Productus pertenuis* Meek.
2. *Derbya crassa* Meek and Hayden.
3. *Chonetes granulifera* Owen.
4. *Spirifer cameratus* Morton.
5. *Aviculopecten occidentalis* Shumard.
6. *Myalina* sp. ?
7. *Rhombopora lepidodendroides* ? Meek.

Ten miles north of Cushing the following fauna was collected from some limestone strata capping Twin hills.

1. *Spirifer cameratus* Morton.
2. *Productus* (*Marginifera*) *splendens* N. and P.
3. *Chonetes granulifera* Owen.
4. *Athyris* (*Seminula*) *subtilita* Hall.
5. *Syntrielasma hemiplicatum* Hall.
6. *Fusulina cylindrica* Fischer.

On the east side of the courthouse grounds at Pawnee there is an outcrop of four feet of limestone, and four feet of fossiliferous calcareous gray clays. Fossils collected from this bed are as follows:

1. *Productus semireticulatus* Martin.
2. *Productus cora* d'Orbigny.
3. *Productus pertenuis* Meek.
4. *Productus nebrascensis* Owen.
5. *Productus* (*Marginifera*) *splendens* N. and P.
6. *Spirifer cameratus* Morton.
7. *Spirifer planoconvexus* Shumard.
8. *Derbya crassa* Meek and Hayden.
9. *Meekella striatocostata* Cox.

10. *Rhynchonella* (*Pugnax*) *uta* Marcou.
11. *Chonetes granulifera* Owen.
12. *Orthis pecosi* Marcou.
13. *Athyris* (*Seminula*) *subtilita* Hall.
14. *Aviculopecten occidentalis* Shumard.
15. *Euomphalus rugosus* Hall.
16. *Fusulina cylindrica* Fischer.
17. *Rhombopora lepidodendroides* Meek.
18. *Zeacrinus* sp.?

The following list of fossils shows the fauna that was found about two miles southeast of Ralston, in a bed of limestone, and marls that appear to be the same as that in Pawnee.

1. *Productus semireticulatus* Martin.
2. *Productus nebrascensis* Owen.
3. *Productus* (*Marginifera*) *splendens*? N. and P.
4. *Rhynchonella* (*Pugnax*) *uta* Marcou.
5. *Derbya crassa* Meek and Hayden.
6. *Spirifer cameratus* Morton.
7. *Spirifer* (*Ambocœlia*) *planoconvexus* Shumard.
8. *Athyris* (*Seminula*) *subtilita* Hall.
9. *Spiriferina kentuckensis* Shumard.
10. *Meekella striatocostata* Cox.
11. *Chonetes granulifera* Owen.
12. *Chonetes lævis* Keyes.
13. *Retzia* (*Hustedia*) *mormoni* Marcou.
14. *Orthis pecosi* Marcou.
15. *Avicuiopecten occidentalis* Shumard.
16. *Aviculopecten* sp. ?
17. *Avicula speluncaria* Geinitz (not Schlotheim).
18. *Myalina subquadrata* Shumard.
19. *Myalina perattenuata* Meek and Hayden.
20. *Astarte* sp. ?
21. *Bellerophon* sp. ?
22. *Lophophylium proliferum* Hall.
23. *Phillipsia scitula*? Meek and Worthen.

The following fauna was collected from sandstone beds that outcrop six to seven miles southwest of Pawhuska along the Pawhuska-Gray Horse road. These sandstone beds are probably one hundred and fifty feet above the Pawhuska limestone.

1. *Pinna peracuta* Shumard.
2. *Schizodus wheeleri* Swallow.
3. *Schizodus rossicus* Verneuil.
4. *Nucula bellistriata* Stevens.
5. *Aviculopecten* sp. ?
6. *Pleurophorus angulatus* Meek and Worthen.
7. *Pleurophorus* sp. ?
8. *Myalina swallovi* McChesney.
9. *Yoldia subscitula* Meek and Hayden.
10. *Pleurotomaria perhumerosa* Meek.
11. *Bellerophon* sp. ?

Descriptions of Species.

Productus (*Marginifera*) *adairensis* sp. nov. Drake. Pl. IX, Figs. 1–3.

Shell small, the largest specimen found being three-quarters of an inch in height, and seventeen-twentieths of an inch in greatest breadth, at hinge line. Beak highly arched, and projecting one-third of the entire height of the shell above the hinge line. Ears slightly extended. Surface ornamented with very fine ribs, and occasional small spines, and in the region of the beak, with a slight reticulation. The ventral valve has a distinct medial sinus, which begins near the beak. The outside of the shell resembles somewhat *Productus multistriatus* Meek, of the Upper Carboniferous, but has the ribs even finer, and the beak somewhat more slender than that species. The inside of the shell shows the characters

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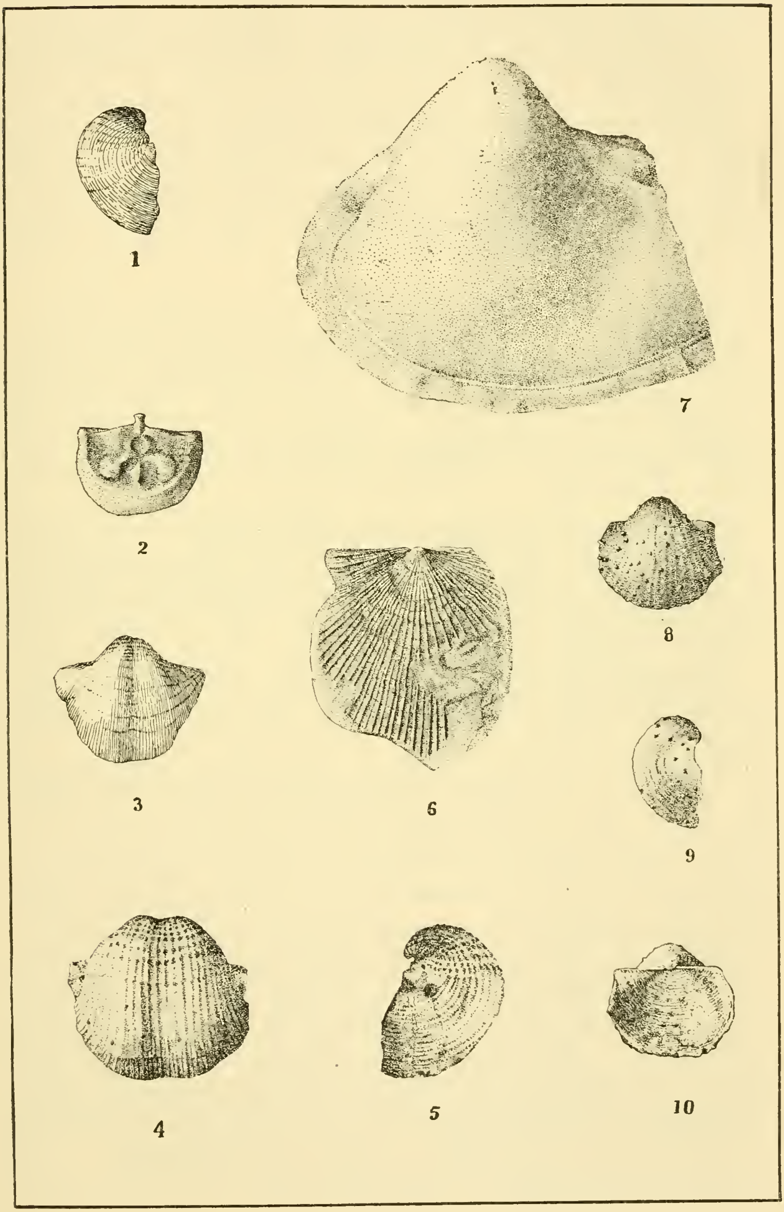
Plate IX.

Plate IX.



assigned by Waagen to his genus Marginifera, although Hall and Clarke have recently shown, in "Nat. History of New York," *Palæontology*, Vol. viii, "Brachiopoda," p. 331, that the genus is not valid, and can have at most subgeneric value. As such it is here retained.

Occurrence and Horizon.—Boone limestone (Burlington-Keokuk), three miles southeast of Westville; Boone limestone, seven miles east of Adair, Pl. IX, Fig. 2; Boston group (St. Louis-Chester), five miles east of Adair, Pl. IX, Figs. 1 and 3. About fifteen specimens collected, altogether.

Productus cherokeeensis nov. sp. Drake. Pl. IX, Figs. 4 and 5.

This species resembles closely *P. semireticulatus* Martin, but is always smaller, more compressed laterally, more highly arched, and has the mesial sinus more pronounced. It is nearest akin to *P. inflatus* McChesney, but the umbo is not so prominent, nor so greatly incurved as in *P. inflatus;* also the ribs seem a little coarser on *P. cherokeeensis.*

The dorsal valve is strongly concave, the ventral is very convex, with strong medial sinus. The surface of both valves is ornamented with distinct ribs, often dichotomous; the region near the beak is distinctly reticulated by the growth lines. There are occasional spines on the surface.

The ears are somewhat more extended than on *P. semireticulatus*, but the total proportional width of the shell is less than on that species.

Occurrence and Horizon.—Rather common in the Upper Boone limestone (Burlington-Keokuk), West mountain, three miles southeast of Westville; in the Fayetteville shale (Warsaw), on Grand river, at Adair's ferry; in the Boston group (St. Louis-Chester), eight miles southeast of Big Cabin, and in the same horizon a half miles south of Vinita; in the Boston group, five miles southeast of Adair, Pl. IX, Figs. 4 and 5. The species is confined entirely to the Lower Carboniferous in Indian Territory, and a very similar form has been found in the Fayetteville shale (Warsaw) of Arkansas, and also in the Marshall shale, probably St. Louis, of that State. It is worth while to separate this species from *P. semireticulatus* from its stratigraphic importance, and because of the unlikeness of the two and the difference of their associated faunas.

Productus pertenuis Meek. Pl. IX, Figs. 8–10.

Productus pertenuis Meek. *Final Report U. S. Geol. Survey Nebraska*, p. 164, Pl. I, Fig. 14, Pl. VIII, Fig. 9.

Productus cancrini Geinitz. *Carbon und Dyas in Nebraska*, p. 54, Pl. IV, Fig. 6 (not Murchison, Verneuil and Keyserling).

The specimens referred to *Productus pertenuis* are rather larger than those figured by Meek, and have somewhat stronger radial ribs. But the thinness of the valves, the great convexity of the ventral valve, the lack of a medial sinus, and the disposition of the small spines all agree with the figures and descriptions of Meek's *P. pertenuis*, and the form referred by Geinitz to *P. cancrini* M. V. K.

Adults of the shell average about three-fifths of an inch wide and the same in height; convexity of the valve for a shell of these dimensions is nine-twentieths of an inch. The shell referred by Meek, *Geol. Expl. 40th Parallel*, Vol. iv, p. 78, Pl. VIII, Fig. 4, to *P. longispinus* Sowerby, probably belongs to *P. pertenuis*, for it lacks the medial sinus, and has the other characters of *P. pertenuis*, except that the beak is not quite so slender.

Horizon and Locality.—Lower Coal Measures, four miles north of Vinita; one mile south of Muscogee: Upper Coal Measures, Cavaniol group, McClellan ford on Verdigris river; Poteau group, six miles west of South Canadian; Permian division, upper bed of sandstone four miles west of McDermitt; Pawhuska sandstone, five miles west of Cushing. The same or a nearly related species also occurs in the Lower Carboniferous limestone, Boston group (St. Louis-Chester), five miles southeast of Adair; a specimen from this locality is figured on Pl. XII, Figs. 8, 9 and 10.

Aviculopecten rectilaterarius Cox. Pl. IX, Fig. 6.

Avicula rectalaterarea Cox. *Geol. Survey Kentucky*, Vol. iii, p. 571, Pl. ix, Fig. 2.

The shell is somewhat semicircular in outline, the greatest length being about equal to the greatest width. The hinge line is straight and nearly equal to the greatest width. The beak is small, rounded, does not project above the hinge line. The rounded anterior ear is rather sharply set off from the rest of the shell, and differs slightly from it in having the radial ribs rather coarser and further apart. The left valve has the base of the anterior ear somewhat notched. The posterior ear, which is longer than the anterior, is not distinctly set off from the rest of the shell, but differs from it in ornamentation, so as to be well marked.

The surface is marked by distinct radial ribs, somewhat narrower than the interspaces. These ribs are often dichotomous, and also increase by intercalation. Near the beak the surface is faintly ornamented with distinct concentric striæ of growth, which grow stronger towards the posterior margin. The ears are ornamented just as the rest of the shell, except that the ribs are somewhat coarser on both anterior and posterior ears.

A. rectilaterarius resembles very closely *A. papyraceus* Sowerby of the European Coal Measures, and indeed a more perfect suite of specimens may show their identity, for many of the species that accompany *A. papyraceus* in Europe have already been found in America.

Horizon and Locality.—Upper Coal Measures, Poteau group, in the shales overlying the Mayberry coal, at the mines four miles northwest of Poteau, Indian Territory.

Schizodus insignis sp. nov. Drake. Pl. IX, Fig. 7.

This species, one of the largest of the genus Schizodus, is represented in the collection only by a cast, so that the generic reference is not beyond doubt. The shell is large, being two and a half inches in length and two inches in height. Convexity of the valve is eleven-twentieths of an inch. The beak is rather high and pointed, rising two-fifths of an inch above the hinge line. The anterior margin is rounded, the posterior is broken off. The anterior and posterior adductor impressions are quite large and distinct. The cast is smooth, so nothing is known of the sculpture of the surface. The only species with which *Schizodus insignis* may be compared is *Schizodus* (*Leptodomus*) *magnus* Worthen, *Geol. Surv. Ill.*, Vol. viii, p. 107, Pl. XVIII, Fig. 2, of the Lower Carboniferous, Chester horizon; but *S. magnus* differs from *S. insignis* in the elongation of the anterior part of the valve, also in the sharp high ridge that runs from behind the beak obliquely to the rear of the shell. Otherwise there is considerable similarity, and the two species may very well belong to the same genus.

Occurrence and Horizon.—In hard sandstone of the Permian horizon, five miles east of McDermitt, Indian Territory; only a single specimen was found.

PART III.

Economic Geology.

The coals of the Indian Territory are at present its most important geologic product. The part of this paper treating of economic geology must therefore be devoted principally to coal.

Coals of the Choctaw Field.

Grady Bed.—The outcrops and workable areas of the Grady coal bed are confined to three continuous narrow belts. One belt encircles the Backbone anticline, one the Bokoshe-Milton anticline, and the other lies at the south bases of the Poteau, Cavaniol and Sans Bois mountains. The bed around the Backbone anticline enters the Indian Territory on the north side of the axis east of Pocola, and runs about S. 80° W. At the Territory line the bed is almost horizontal, or dips slightly to the north, as shown in Section No. 5, which was made across the Backbone anticline southeast of Pocola.

One mile west of Pocola the coal bed dips 15° to 20° to the north; the coal is three feet and seven inches thick, and has one thin parting of shaly coal nineteen inches from the bottom of the bed. Fire clay underlies the coal and arenaceous clay shale overlies it. The increased dip of the coal bed to the west from the Territory line is probably due to the decrease in the throw of the fault along the north side of Backbone mountain, so that the strata enter into the anticlinal fold. It is possible that the Poteau river west and north of Pocola runs along a gentle anticline; if so, the coal bed is deflected down that stream on either side. The dip of the rock west of Pocola, however, does not make this probable. At any rate, a few miles west of Poteau river along the general direction of the coal outcrop, the dip of the rocks shows conclusively that the bed is continued westward from that place. The coal bed has been opened near the Kansas City, Pittsburgh and Gulf Railway at several places on either side of Buck creek prairie and east of Poteau river. This coal is being worked to a very limited extent a half mile east of Poteau river and a half mile south of James fork of Poteau river; the coal at that place is twenty-eight inches thick, dips 10° S. and is overlain and underlain by black clay shale. The bed increases in thickness towards the west, so that a few miles west of Poteau river it is four feet thick. The Bokoshe-Milton anticlinal fold brings this coal bed up so that its outcrop swings around that anticline. This outcrop has been prospected along most of its length at intervals of one-fourth to one-half mile.

West of Ward the coal is four to five feet thick and dips 25°. Southwest of Ward, at the Coleman place, a well passes through six feet and two inches of coal, including a parting of very shaly coal one and a half inches thick, two feet from the top. One-half mile further south the coal is said to be five and a half feet thick. The dip of the coal bed increases slightly toward the south for a mile or two. South of Bokoshe it is about four feet thick and dips 25°. One and a half miles east of Milton the coal is three feet eight inches thick. A half mile south of Milton, at the Ward Brothers' coal bank, the coal bed is parted by twelve to eighteen inches of shale; the upper stratum of coal is twenty-six inches and the lower forty-four inches thick. Gray clay shale underlies and overlies the coal. A half mile further west the coal bed is parted by five inches of shale, the upper stratum of coal is twenty-two inches thick and the lower four feet two inches thick; the dip is 23°. A half mile still further west the upper stratum of coal is twenty-eight inches thick, the shale parting three inches; only about four feet of the lower stratum of coal was seen, and the bed is a little thicker than that; dip of bed 22° S.

Farther to the west the coal slightly decreases in thickness, while eastward and northward on the north side of the loop it decreases rather rapidly, until it is about eighteen inches thick west of Bokoshe, and about fourteen inches thick northwest of Bokoshe.

This coal bed dips southward under the Sugar Loaf, Poteau, Cavaniol and Sans Bois mountains and comes to the surface again on the south side of those mountains, as shown in Secs. 1, 2, 3 and 4. The coal bed along this south line of outcrops is often split by partings varying in thickness from a few inches to fifty feet, and several thin strata of coal are common near the main bed. The following section, from a railway cut one and a quarter miles south of Heavener, shows the nature of this coal group at that and a number of other places:

	FEET.	INCHES.
Shale	2	
Coal		8
Shale	15	
Shaly coal	1	
Shale and streaks of coal	5	

	FEET.	INCHES.
Coal		6
Carbonaceous shale	1	6
Coal		2
Carbonaceous shale	2	
Coal		4
Carbonaceous shale	1	6
Coal		1½
Carbonaceous shale	1	6
Shale	15	
Sandstone	25	
Shale	12	
Sandstone	5	
Shale	2	
Coal		1
Carbonaceous shale		11
Coal		1½
Carbonaceous shale		6
Coal		2
Shale		3
Coal		1
Shale		2
Coal	1	
Shale	4	
Coal	2	

Three miles east of this section the coal is two feet six inches thick. One and a half miles southwest of Heavener it is twenty-eight inches thick. Three miles northwest of Heavener the coal has been mined considerably and is said to be about four feet thick.

This coal has been mined quite extensively where it is touched and crossed by the St. Louis and San Francisco Railway. At the most easterly point touched by the railway, a place once called Pocohontas, the coal lies in two beds separated by about fifty feet of shale; the upper coal bed is thirty-seven inches thick and the lower one forty-four inches, and the bed dips about 45°.

At Wilburton preparations for extensive coal mining were being made in 1896. The coal occurs in two beds separated by about fifty feet of shale. The upper bed is about four feet thick; the lower one was not accessible in 1896, but the superintendent of the mine reported it a little over four feet thick. The coal is apparently of uniform good quality. This bed is now being worked extensively at Cherry Vale, about three or four miles northeast of Krebs, where it averages about three feet four inches thick, is uniformly good and dips about 12° N. From this mine the coal outcrop runs but little farther west before it swings to the south and then turns east some twenty miles, when it again swings to the south and back west again, thus forming an S-shaped outcrop at this place. The eastward loop of the S outlines a small synclinal basin called by Dr. H. M. Chance the Grady basin.[1] Coal is extensively mined in this basin at Hartshorne. The coal is composed of one four-foot bed, which is worked, and other higher, thinner beds, not worked. The synclinal fold, forming the basin, is a gentle one so that the dip of the rocks on its sides are only 4° to 5°. Chance[2] says: "The maximum depth of the Grady coal bed in this basin is about 600 feet; but over three fourths of the basin the bed can be reached at depths less than four hundred and fifty feet, and over one-half of the basin the depth will probably not exceed three hundred feet. The basin is about six miles long by three or four wide and contains over 11,000 acres of the Grady bed. Throughout this area the coal is not always of workable thickness; but over a large portion of it the bed will range from three and a half to five feet thick, yielding an average of four feet of clear coal."

This coal outcrop west of Hartshorne is so broken by faults and tilted by very irregular folds that it is not easily located. The three-foot bed of coal that outcrops in Brushy creek, about five miles west of Hartshorne, appears to be the Grady bed. Here it shows a fault of four or five feet and dips to the southwest 5° to 6°. About two miles further west, that is, seven miles west of Hartshorne and one-fourth of a mile northeast of the Brunton place, this coal outcrops again and is three feet eight inches thick, but with two partings of shaly coal in it. One three to four-inch parting is within three inches of the base, and ten inches from the base of the bed there is a shaly parting from one to two inches thick.

McAlester Coal Bed.—The outcrop of the McAlester coal bed is greater than that of the Grady bed, since it does not lie so deep and does not require such excessive foldings to bring it up or such profound erosion to reach it. The outcrop is shown on Pl. I

[1] *Trans. Am. Inst. Min. Eng.*, Vol. xviii, p. 654.

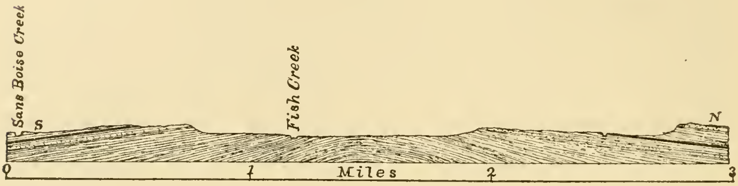
[2] *Ibid.*, p. 659.

with the exception of areas near the Canadian and Arkansas rivers and around the base of Sugar Loaf and Poteau mountains. These latter places were not sufficiently examined to locate the line of outcrop. This coal bed varies in thickness from about one and a half to about four feet. The thickest part of the bed is in the southwest part of the field or about McAlester, Krebs and Alderson. It appears to thin gradually eastward and northward. In the northern part of the field it is almost regularly eighteen inches thick. This bed is now, and has been for some time, extensively mined at Alderson, Krebs and McAlester. The coal bed at Alderson and Krebs is about three feet six inches thick. One-half mile southwest of McAlester, at D. Edwards & Son's mine, the coal is four feet thick. The dip of the coal bed from Alderson to McAlester varies from about 6° to 25°; the gentler dips are at and near Krebs. The outcrop northwest, north and east of McAlester for some distance lies along a faulted area, so that the coal bed occurs in blocks dipping irregularly and usually at very steep angles. In this faulted area no place has yet been worked extensively and profitably. Farther to the east the coal has not been found sufficiently thick to pay for working. Southeast of Red Oak it is two feet thick and dips 20°. North of Red Oak, in Brazil Creek valley, it is about two feet thick and dips very gently.

At and near Fanshaw the coal is thirty inches thick, dips about 25° and was once considerably but unprofitably mined. About five or six miles east of Fanshaw, in Big Caston creek, the coal is twenty-eight inches thick and dips 35°. The coal once mined at the west edge of Poteau seems to be this bed; it is said to be about two feet thick at that place.

About two and a half miles southwest of Cameron this coal is eighteen inches thick and dips to the southward 2° to 3°. It is occasionally mined to a limited extent by stripping. At this place there is a shale parting in the bed six inches from the base of the coal. In wells on the farm of Mr. Henry Choate, about four to four and a half miles west of Brazil, this coal is reported to be from two to two and a half feet thick. About three miles south of Milton, in Owl creek, near its mouth, this coal bed is eighteen inches thick; some six miles further west in Owl creek, one-fourth mile east of Haney Smith's, the coal is only thirteen inches thick; the dip of the bed about 20°.

Southeast of Sans Bois, along Mountain Fork of Sans Bois creek, the coal is a little more than a foot thick at the places where it was seen. About three miles west or north of west from Sans Bois, on a branch of Fish creek, in Mr. Scott's pasture, this coal is seventeen inches thick; dips 4° to 5° N. 10° W.



Sec. 14. Across the Sans Bois anticline, four miles west of Sans Bois.

The above cut shows the structure four miles west of Sans Bois. About seven miles west of Sans Bois, in Beaver creek, the coal is fifteen inches thick. About four and a half miles east-northeast from Sans Bois and one-fourth of a mile east of Mr. Ben Noel's place, this coal is eighteen to twenty inches thick; four miles north-northeast of Sans Bois, in the banks of Sans Bois creek, it is eighteen to nineteen inches thick. About three miles north of Sans Bois, along Cedar creek, the coal is eighteen to twenty inches thick, and dips, 5° to 10°. Two miles west of Iron Bridge this coal is twenty-six to twenty-seven inches thick and quite uniform throughout. About four miles west-southwest from Cashier the coal is eighteen inches thick. Two miles west of Stigler, in Cane prairie, the coal is twenty-eight inches thick and of excellent quality. On Rock branch, one mile west of Whitefield, the coal is twenty-seven to twenty-eight inches thick. The Canadian river, north and northeast of Whitefield, appears to run along an anticlinal fold. If this is the case, the east end of the coal outcrop, west of Whitefield, follows down the east side of Canadian river valley and joins the coal outcrop running northward from east of Whitefield; the westward extension of the coal outcrop, west of Whitefield, ascends Canadian river valley probably nearly opposite Brooken before crossing that river and running back east and northeast by Starvilla, as seems to be the case.

Mayberry Coal Bed.—This coal was not located in the Sugar Loaf or Poteau mountains, but it is doubtless represented there. The coal in the east end of San Bois mountains, at some three hundred to four hundred feet above the base of the mountains, and that on the north side of the mountains near the west end, probably belong to this bed. Sans Bois mountains were not studied closely enough to outline the coal outcrop. The final disappearance of the Mayberry bed, under the westward dipping strata, is shown by the coal outcrop located west and southwest of Enterprise. This coal bed is being mined quite extensively in the east end of Cavaniol mountain by the Kavanaugh Coal, Coke and Railway Company. The bed at this place averages about three feet eight inches in thickness and dips slightly to the southwest. On the opposite side of the cañon, from where it is worked and about one hundred and forty feet lower, there is what appears to be another bed of coal. This lower bed contains some shale, as is shown by the following section:

	FEET.	INCHES.
Coal		5
Clay shale		1½
Coal	1	
Shale		9
Coal	2	6

The layers of shale found in this lower bed and its difference in elevation indicate a different horizon from the one that is being worked, but it seems possible, from the cursory examination made, that they may be the same bed. If they are not the same bed, the lower or more shaly bed is probably a local deposit, for but one coal bed of importance was found at other places over the field at the horizon of the Mayberry coal.

On the north side of Cavaniol mountain, at the original place of discovery of the Mayberry coal, the beds show the following sequence:

	FEET.	INCHES.
Coal	1	5
Clay shale		3
Coal		8
Clay shale		3
Coal	1	10

This coal is a short distance above the fourth thick sandstone bed of the Cavaniol mountains.

A coal bed eighteen inches thick outcrops in the northeast end of

Sans Bois mountains one mile south of Henry Blaylock's house and three hundred or four hundred feet up on the mountain side. It is quite uniformly good except one and a half inches of shaly coal three or four inches from the bottom of the stratum. The coal is overlain by sandstone and underlain by clay. This coal was traced one-half mile or more around the hillside and was about the same wherever it was seen. From its position it seems to belong to the Mayberry coal bed. The coal near the head of Ash creek and near the west end of the Sans Bois mountains is said to be about eighteen inches thick. The bed that appears to represent the Mayberry coal, along the western border of the folded area, is from eighteen to twenty-four inches thick and of a good quality. About four miles northeast of Reams, at the west end of Sans Bois prairie, this coal is twenty-four inches thick. The bed is very much fractured at this point, which is on the axis of the Sans Bois anticline. About eight miles south of Enterprise and one and a half miles southwest of Russelville, along the head waters of Old Town creek, the coal is twenty-nine inches thick, including a thin parting of shaly coal eight inches from the base and another seven inches from the top. On the southwest side of McChar mountain, along the head waters of Long Town creek, the coal is nineteen inches thick. One-half mile above the mouth of Old House creek, it is twenty-one inches thick. The coal outcrops on Haytubya creek one-half mile from its mouth and about six miles west-southwest from Enterprise. At this place it is twenty-three inches thick and good throughout, but closely fractured by lines a half to one inch apart; dip of bed 2° to 3°. About four and a half miles west-southwest from Enterprise, the coal has been worked to some extent by stripping. At that place it is twenty-two inches thick and uniform throughout. One and a half miles north of Enterprise, the coal is twenty-six inches thick and is worked for local demands by stripping.

Coals of the Cherokee and Creek Nations.

In those parts of the Indian Territory lying within the Cherokee and Creek Nations the coal beds were not traced in detail, and were seen usually only at widely separated intervals, and cannot therefore be definitely outlined in this discussion. However, the structure of the area is quite regular, so that the general extent and connections of the various coals can be fairly well outlined.

Grady Coal.—The lowest coals found through the Cherokee and Creek Nations will be discussed under this heading, though it is doubtful whether they represent the northern continuation of the Grady bed, or whether they all belong to the same bed. The northern and eastern limit of the Cavaniol group, as outlined on the accompanying map, shows the approximate outcrop of this coal bed. The following local developments were seen: About one mile east of Little Salisaw creek, and one-fourth of a mile south of the Kansas City, Pittsburgh & Gulf Railroad, this bed of coal outcrops and has been worked to some extent by stripping. The coal is said to be one and a half feet thick and of good quality. The strata overlying the bed dip 15° to 20° north-northwest. About three miles southwest of Salisaw Station the same coal outcrops along Coal creek. It is one to one and a half feet thick, and has been mined by stripping. This coal was, in the summer of 1896, being used by blacksmiths in Salisaw, who pronounce it an excellent one for their work. The mines were all filled with water at the time the writer visited the place. Along the south side of Spaniard creek, at the Weber's Falls-Muscogee road crossing, the coal bed is ten to twelve inches thick and is mined for local demands. The bed dips north-northwest about 12°. Going from this point toward Muscogee, the synclinal basin is crossed at right angles and the coal outcrop is again seen about four miles southeast of Muscogee. The eastern end of this synclinal fold lies near Braggs, where the bed has been worked a little. It outcrops along branches about two miles south of Braggs, and is four to six inches thick. It is said to underlie Braggs at an average depth of about thirty feet and is six inches thick. Five miles west of Muscogee and one mile south of the Arkansas river, this coal has been worked a little. At that place the coal is eight to twelve inches thick. It outcrops again four miles north-northwest of Adair, along the side of an east-facing escarpment. Where it was seen (the Ross coal bank), the coal is seventeen inches thick, underlies a gray shale and is apparently rather high in ash and sulphur.

This coal outcrops along Log Cabin creek, about three miles west of Welch, where it is said to be about two feet thick, and is mined for local demands.

McAlester Coal Bed.—This coal outcrop is approximately located on the map from near Starvilla to Dirty or Elk creek, northeast of Checotah. One and a half miles northwest of Starvilla the coal is about two feet thick. It is mined to some extent along the Thomas fork of Elk creek, at a place about six miles east of Checotah, where it is about fourteen inches thick. Along Elk or Dirty creek, about four miles east of Checotah, the coal is eighteen to twenty-four inches thick. From Starvilla to Elk creek, and doubtless much farther, a five to six-inch seam of coal occurs regularly fifty to seventy-five feet above the McAlester bed. These beds in the Choctaw coal field are separated by about one hundred feet of gray clay shale.

The McAlester coal outcrops six or seven miles southwest of Muscogee, where it is about one foot thick and is worked for local demands.

Another outcrop was seen four or five miles west of Chelsea, where it was worked at several places for local demands. At the Robinson bank it is eighteen inches thick, and of uniform quality throughout. At the McFadden coal bank the same qualities are shown.

About a hundred feet above this bed and four miles farther west, a coal bed fifteen inches thick outcrops. It is also worked somewhat for local use by stripping. This bed is probably not represented south of the Canadian river, but the outcrops along Coal creek, twelve miles east-northeast from Okmulgee, and those five to six miles southwest of Chelsea, are probably the same. On Coal creek the coal is about fifteen inches thick and quite uniformly good. The bed dips 1° to 3°, is overlain by carbonaceous clay shale, and underlain by fire clay. Southwest of Chelsea the coal is about ten inches thick and of very good quality.

Mayberry Coal Bed.—The coals occurring at the top of the Cavaniol group, and that probably represent the northern extension of the Mayberry bed, were seen as follows:

The upper bed outcrops along Coal creek, twelve miles south of Okmulgee, where it is parted by from four to eight inches of shale and shaly coal. The upper stratum of coal is fourteen inches thick and the lower one is from fourteen to sixteen inches thick. Both strata are apparently good, but iron pyrites is rather common in places through the coal. In general appearance this coal is almost identical with that occurring four or five miles west of Chelsea, and the chemical analyses show them to have the same general properties. The next outcrop of this coal bed was seen along Coal creek, about six miles east of Sapulpa. At that place it is from twenty-two to twenty-four inches thick where it was examined, and has three to four shale partings, which are from a quarter to half an inch thick. Gray clay shale overlies the coal. The Mayberry coal bed was seen next at a place three miles northwest of Oologah, where it is two feet thick and rather uniform throughout. It is mined rather extensively by stripping for shipping to distant markets as well as for local demands. This same bed outcrops along Little Verdigris or Caney river at Mustgroves crossing, where it is about one and a half feet thick, according to report.

These local developments show that the best coals of the Cherokee and Creek Nations are only about two feet thick, but that they extend through the entire length of the Nations.

Coal Analyses.—At each locality where coals were collected for analyses, samples were selected to represent the average coal of that particular place; but as no guide save the appearance of the coal could be used in sampling, the analyses will necessarily not show the quality of the coal as well as may be desired. They will, however, show fairly well the characteristics of the coals and their adaptability to various uses.. In the table of coal analyses the coal beds are placed in the same relative position that they occupy in the field, so that the Mayberry coals are first or at the top, the McAlester coals in the centre, and the Grady coals at the bottom. In each group the analyses begin with coals in the west and northwest part of the field and proceed eastward and southeastward. The groups thus proceed from higher to lower coals; the analyses of each group, and the groups also to some extent, run from a region of less to a region of greater folding and crushing. This arrangement clearly shows the decrease in the bituminous nature of the coals toward the region of greater dynamic movements. The coals are practically all bituminous, only that from near the mouth of James fork of Poteau river and that from near Milton being semi-bituminous. All the coals show a probability of coking, and a considerable quantity of slack coal from mines at Alderson and Krebs is now being coked. Most of the coals, however, are too high in sulphur to produce good coke for metallurgical uses. Some of the coals are objectionably high in sulphur, water, or ash, but as a whole they compare favorably with good coals from other fields.

Coal Oil.—During the summer of 1896, several wells were sunk, two hundred to three hundred feet deep, along Spencer creek val-

Coal Analyses by N. F. Drake.

Bed.	Locality.	Thickness of Coal Beds.	Water.	Volatile Hydro-Carbons.	Fixed Carbon.	Ash.	Sulphur.	Fuel Ratio.	Color of Ash.	Coking Tests.	Remarks.
Mayberry Bed.	Three miles northwest of Oologah, Cherokee Nation.	1′ 0″	3.35	34.99	57.88	3.15	1.21	1.65	Light yellow.	Fused and doubled in size.	
	Four miles east-northeast from Reams, Choctaw Nation.	2′ 0″	1.62	32.92	55.79	9.65	. . .	1.69	Lavender.	Fused and increased one and a half times.	Sulphur not determined.
	Twelve miles south of Okmulgee, Creek Nation.	2′ 4″	6.31	30.78	59.92	2.11	0.87	1.94	Light yellow.	Fused and increased in size one and a half times.	
	Six miles west-southwest of Milton, in north end of Sans Bois mountains.	1′ 6″	0.95	31.71	57.75	9.57	. . .	1.82	Brick red.	Fused and increased in size about ten times.	Sulphur not determined.
	Four miles northwest of Poteau, Choctaw Nation.	3′ 8″	1.36	17.23	64.54	12.46	4.40	3.80	Reddish brown.	Fused and increased in size about ten times.	
	Eight miles west of Chelsea, Cherokee Nation.	1′ 3″	2.77	34.61	56.17	6.43	. . .	1.62	Brick red.	Fused and increased in size about five times.	Sulphur not determined.
McAlester Bed.	Four and a half miles west of Chelsea, Cherokee Nation.	1′ 6″	6.26	27.16	64.17	1.84	0.56	2.36	Yellowish white.	Fused and increased in size one and a half times.	
	One-half mile southwest of McAlester.	4′ 0″	3.33	29.75	61.78	4.37	0.75	2.07	Yellowish brown.	Fused and increased one and a quarter times.	
	Alderson, Choctaw Nation.	3′ 4″	2.35	32.42	58.47	4.32	2.42	1.80	Light lavender.	Fused and increased in size one and a half times.	
	Three miles north-northwest of Sans Bois.	1′ 6″	1.60	24.83	68.69	2.95	1.90	2.76	Reddish brown.	Fused and increased in size about ten times.	
	One and a half mile northwest of Starvilla, Cherokee Nation.	2′ 0″	1.25	22.49	62.18	7.88	6.18	2.77	Brick red.		
	Two miles west of Stigler, Choctaw Nation.	2′ 4″	1.66	23.01	72.49	1.92	0.91	3.15	Light yellow.	Fused and increased in size about ten times.	
	Two miles west of Iron Bridge.	2′ 3″	1.21	19.67	73.46	3.40	2.25	3.75	Brick red.	Fused and increased in size about ten times.	
Grady Bed.	Cherry Vale mine, Choctaw Nation.	3′ 4″	2.54	30.90	62.37	3.56	0.60	2.01	Yellowish brown.	Fused and increased in size very little.	
	Hartshorne.	4′ 0″	2.69	35.65	54.91	4.12	2.62	1.54	Reddish brown.	Fused and increased in size one and a half times.	
	Upper stratum of coal bed, one-half mile south of Milton.	2′ 2″	1.12	14.23	77.31	4.04	3.28	5.43	Lavender.	Fused and increased in size about eight times.	
	Lower stratum of coal bed, one-half mile south of Milton.	4′ 2″	0.98	13.60	73.84	7.83	3.72	5.43	Lavender.	Fused and increased in size about eight times.	
	One and a half mile southwest of Heavener.	2′ 4″	3.67	19.46	72.83	3.28	0.74	3.74	Light yellowish brown.	Fused and increased in size but very little.	
	Near the mouth of James fork of Poteau river, Choctaw Nation.	2′ 4″	1.20	13.75	82.95	1.16	0.92	6.03	Yellowish brown or nearly orange.	Fused but increased very little in size.	

ley, four to five miles west of Chelsea. Some of the wells flow, but none of them produce very much oil. The foreman of the works informed me that the greatest flow of any one well was about a barrel per day, and that the oil was struck in a micaceous shaly sandstone. This sandstone is probably the bed that outcrops east of Chelsea, and lies between the two lower coal beds. The rock beds are practically horizontal in the area where the oil wells have been sunk, but the strata passed through, in sinking the wells, come to the surface farther eastward. The oil is probably derived from the Lower Coal Measures shale beds that outcrop along the Missouri, Kansas & Texas Railway, east of Chelsea.

Building and Ornamental Stone.—The sandstones, limestones, marbles and granite that occur in this field are adapted to many uses in construction work. Sandstones are very abundant, except in the Boone chert area, throughout almost the entire field. They are usually evenly textured, massive, tough, and are well adapted for ordinary building purposes. The best limestones for building purposes are confined to the Lower Carboniferous and especially to the upper Boone limestone horizon. Massive beds of tough gray evenly-textured limestone are common in the Boone limestones. The Boston group also contains some good building limestones and occasional thin beds of limestone were seen in the Permian area that are fairly good for building purposes. The outcrops of the marble beds are shown in Pl. IV. Massive beds of marble, twenty-five to thirty feet thick, outcrop at nearly every marble area shown in that plate. The thickness of the marble beds has not yet been determined, but from drill borings it appears to be one hundred and fifty feet or more. The marble is usually pink colored, but some of it is gray and a little is practically white. So far, the marble that has been quarried contains a great many fractures and rather abundant small cavities, partly or entirely filled with large calcite crystals. Further investigation may result in finding better marbles than the surface outcroppings. Some of the bed that is at present being quarried can be advantageously used for building and ornamental uses.

The granite found on Spavinaw creek is an excellent stone for building and ornamental purposes, but it is at present too far from any railway to be profitably quarried for marketing. For a more extended discussion of the various kinds of rock previous pages may be consulted.

Stated Meeting, September 17, 1897.

Vice-President PEPPER in the Chair.

Present, 16 members.

Correspondence was submitted and donations to the Library were reported.

The announcement of the decease of William S. Baker, a member of the Society, on the 8th day of September, æt. 74 years, was made.

Mr. R. P. Field presented a communication on "The Span of Life."

Mr. Henry C. Mercer made some remarks on the "Survival of the Art of Illuminating Manuscripts among the Germans in Eastern Pennsylvania."

The Committees on By-Laws and Finance presented reports.

The Society was adjourned by the presiding officer.

THE SPAN OF LIFE.

BY ROBERT P. FIELD.

(*Read September 17, 1897.*)

On Thursday, February 28, 1895, the *Evening Bulletin*, a daily journal published in Philadelphia, had an editorial upon long life in Philadelphia, referring to an address by Dr. Lawrence Turnbull on "Longevity and Personal Hygiene," in which he presented an array of facts with regard to the advanced age of some of our best known men, and said: "The Biblical idea of three-score years and ten is gradually ceasing to be the limit in our day, owing to better sanitary laws and regulations," which this journal states is in direct opposition to the common belief that, in the United States at least, the activity and restlessness of the people are tending to shorten the period of life enjoyed by the average man. This belief, it says, is entirely reasonable owing to the greater hurry and cram of the people of this country, and in view of the fact that they sleep less and hurry more over their food than do the people of other nations.

The editorial goes on to say, for instance, that the late Dr. Oliver Wendell Holmes believed that the life of a poet is generally not long; yet refers in his writings to Longfellow, Halleck and Whittier, all of whom attained to over seventy-five years of age and one of them to eighty-five, and that Holmes himself was eighty-five when he died. Other well-known men are cited by Dr. Turnbull as examples of longevity; for instance, Mr. Gladstone living at eighty-five, Bismarck at eighty, Pope Leo XIII at eighty-five, and in our country Senator Morrill, of Vermont, eighty-four; ex-Senator Payne, eighty-five; Neal Dow, of Maine, ninety-one; Robert C. Winthrop, eighty-seven; ex-Secretary McCulloch, eighty, and ex-Senator Thurman, eighty-one, in addition to whom he mentions Dr. William H. Furness and the Hon. Frederick Fraley. The apparent conclusion reached by the paper is that long life in America is not uncommon, and that, therefore, the average age is greater than the so-called three-score years and ten.

This editorial was penned more than two years ago. My attention was called to it by Dr. J. Cheston Morris, who knew that I was interested in such matters. The remark by Dr. Turnbull on the "Biblical idea" aroused my curiosity and a desire for investigation. As some of the names mentioned in this paper appear upon the rolls of the American Philosophical Society, it seemed as if the "experience" of the Society in this direction would be interesting. The "experience" of the Society does *not* bear out the assertion of Dr. Turnbull if his statement be taken to mean that nowadays the average life is greatly prolonged beyond the "three-score and ten."

In the general list of the members of the Society from 1743 to 1894, inclusive, there have been 1118 deaths where the ages have been recorded. The average age at death is seventy and one-eighth years. The youngest age is twenty-five (25) years. Two deaths are recorded at that age, Dr. John Pennington and Joel B. Reynolds. The oldest age at death was Dr. Ed. Holyoke, of Massachusetts Bay, having died at the advanced age of one hundred and one (101).

The average length of membership is found to have been twenty-two and sixty-four one-hundredths years (22.64). The shortest membership is that of Capt. Karl Chevalier Rousseau d'Happoncourt, who was a delegate from K. K. Military and Geographical Institute of Vienna on the occasion of the Society's sesqui-centennial, was elected to membership October 20, 1893, and unfortunately died only six days afterwards, on the 26th.

The longest membership was that of Thomas Bradford, who was elected May 18, 1768, at twenty-three (23) years of age and died on May 7, 1838, at ninety-three (93), having been a member seventy (70) years, less eleven days.

Six cases show a membership of sixty-five (65) years and over.

The average age at entry (or at election) was forty-seven and forty-nine one-hundredths (47.49) years.

From the *record* it would appear that several persons were elected at a very early age—Rev. Henry Steinhauer as early as thirteen (13), but there are so few that this error (if it be one) could not affect the general finding.

The general deduction from this study shows:

1118 members entering at an average age of....47.49
1118 members living after election a total of
25,312 years or averaging..................22.64
1118 members living 78,403 years or averaging
at death.................................70.13

It is exceedingly interesting and instructive to note that comparng this with the "American Experience Table of Mortality," calculated from the experience of the insurance companies, we find that

Persons living at the age of forty-seven and a
half.....................................47.50
May be expected to live for twenty-two seventy-
two one-hundredths years..................22.72
Or to reach the average age of...............70.22

But the editorial refers to "the common belief that, in the United States at least, the activity and restlessness of the people are tending to shorten the period of life enjoyed by the average man." In order to see whether the American members live a shorter time than others, or whether the "leaven" of the foreign element has increased the apparent longevity, a study was made of the "experience" of the American members alone for twenty-five years.

The record was studied with reference to the deaths which have occurred during the twenty-five years ending December 31, 1894. Three hundred and fourteen (314) members died during this period. the ages of two hundred and ninety-three (293) of whom are known

The result of the study of these shows :

Two hundred and ninety-three members entering at an average age of.............. ....48.57
Two hundred and ninety-three members living after election a total of 6253 years, averaging.21.34
Two hundred and ninety-three deaths of members living a total of 20,484 years, or averaging..................................69.91

Even this small number shows a fairly close agreement with the tables.

This shows practically the same result as that given above. This result bears out the mortality tables and the "Biblical idea."

The table shows that people aged........	48.57	years
Might be expected to live..............	22.00	"
And reach the age of..................	70.57	"

which is but sixty-six one-hundredths of a year longer than this actual "experience," a variation easily accounted for by the small number making up the "experience."

Some years ago I had occasion to look up the "experience" of clergymen in connection with some of the different Protestant denominations. In this study the records of eight denominations were consulted, involving seven thousand six hundred and twenty-two (7622) lives, who lived 495,967 years, or an average of 65.07 years.

The average age at which a man enters the ministry is from twenty-five (25) to thirty (30) years, averaging, say, twenty-eight (28) years.

By looking at our "American Experience Table" again, we find the "expectation"

For those entering the table at twenty-eight years is...............................	37	years
If we add the entering age to this..........	28	"
We get...............................	65	years

which is almost exactly the experience of these ministers.

Returning to the records of the Society we find that on December 31, 1894, the longest term during which any one still living had been a member was fifty-five (55) years, Mr. Martin H. Boyé, who was elected January 17, 1840, being still alive. The next longest term was that of Prof. E. Otis Kendall, LL.D., who was elected January 21, 1842, or fifty-three years previous. Our President, Hon. Frederick Fraley, LL.D., was elected July 15, 1842, and had lived for fifty-two and one-half years. The average length of membership of the living members on that date was sixteen and one-half years (16.05), but this count includes only the American members, of whom there were three hundred and thirty-seven (337).

While to a certain extent the average health may be improving, it will take long periods of time for the predictions of physicians to falsify the mortality tables. In this connection it might be well to note that the records of the Board of Health of Philadelphia show that, one year with another, while improved sanitary conditions modify the fatality of certain zymotic diseases, the death rate in Philadelphia remains practically stationary and at about two per cent.

THE SURVIVAL OF THE MEDIÆVAL ART OF ILLUMINATIVE WRITING AMONG PENNSYLVANIA GERMANS.

BY HENRY C. MERCER.

(*Read September 17, 1897*).

The notion of a novel collection was suggested to me by a visit paid last April to the house of an individual who has long been in the habit of buying "penny lots" of so-called trash at country sales. There, scattered in confusion about the premises, rusting, warping and crumbling, lay a heterogeneous mass of objects of wood or iron, which by degrees I recognized as of historic value. Forgotten by the antiquary, overlooked by the historian, they were the superannuated and cast-away tools of the Pennsylvanian pioneer. Because they illustrated, with the fidelity of visual facts, the felling of the forest, the building of the log cabin, cooking in the open fire and the disused arts and crafts, professions and amusements of colonial times, I gathered them together and, ransacking Bucks county for other specimens, stored them by the wagon-load in the museum of the Bucks County Historical Society, at

Doylestown, as a novel and hitherto unattempted illustration of the American beginning.

Among the manifold suggestions involved in the genealogy of such objects as the reaper's cradle, the American carpenter's hatchet and pitching axe, the Dutch scythe and the wooden plow, carrying investigation from America to various parts of Europe, a rude, lidless paint-box, fastened with wooden pegs, long puzzled us.

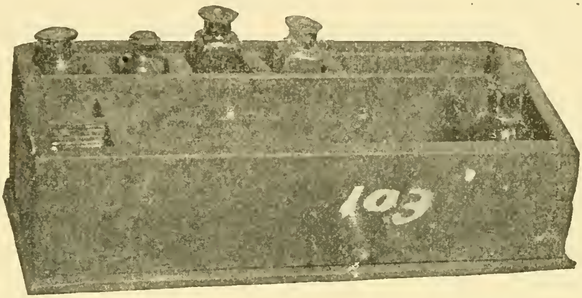


FIG. 1. Paint box used by German schoolmaster about 1820 in the execution of Fractur or illuminative German handwriting. Museum, No. 103, Bucks County Historical Society. Presented to the Society by Tobias Nash, of Wormansville.

About a foot long by six inches broad, with several compartments containing little glass bottles, it was finally explained as one of the color-boxes of teachers of the German schools, superseded in Bucks county fifty years ago. Using it as a receptacle for their home-made pens, brushes and colors, they had instructed scholars in the art of Fractur or illuminative handwriting until about the year 1840.

With great interest, we learned that the time-stained box found in one of the garrets of Bedminster had long ago in its longest compartment contained goose-quill pens, and brushes made of the hair of the domestic cat; that the caked colors in the small bottles had been the home-mixed inks and paints of the master once liquefied in whisky, and that the varnish was composed of the gum of the cherry tree diluted in water.

Working with these primitive tools, often lit at his task, let us suppose, by the once familiar boat-shaped lard lamps suspended upon trammels of wood, the pioneer schoolmaster at the log schoolhouses produced in the latter part of the last century and the beginning of this, the beautiful illuminated hymns (see Plate V) and ornate title-pages which when found in numbers among Mennonites in central Bucks county astonished and delighted us for the first time in August, 1897.[1]

These glowing relics of the venerable stone farmhouses of eastern Pennsylvania, sometimes falling to pieces through carelessness, sometimes preserved with veneration between the leaves of large Lutheran Bibles, revealed by degrees to our investigation the following facts:

First, That the art of Fractur was not confined to Bucks county or to the Mennonites, who had presented us with the first specimens seen, but that it had flourished throughout Pennsylvanian Germany, among the Dunkers, the Schwenkfelders and probably the Amish and Moravians.

Second, That it had been chiefly perpetuated by deliberate instruction in German schools by German schoolmasters, and that it had received its death blow at the disestablishment of the latter in Bucks county in 1854.

Third, That the art, always religious, had not been used for the decoration of secular themes, such as songs, ballads or rhymes, but had expressed itself in

A. Illuminated Song Books,

Such as the beautiful manuscript song books called *Zionitischer Rosen Garten*, and *Paradisisches Wunder-Spiel*, made by the monks at Ephrata, and presented by Mr. Abram H. Cassell to the Pennsylvania Historical Society.

B. The Title-pages to Small, Plain Manuscript Mennonite Song Books,

Often giving the owner's name, with the date and the writer's school, with illuminated borderings, overhanging tulips or lotus, birds and angels blowing trumpets. For example:

[1] The observation was made while my *Tools of the Nationmaker* was in press, on August 20, 1897. I called attention to the special discoveries made in Bucks county in *Science* (See *Survival of the Art of Illuminating Manuscripts among the Germans in Eastern Pennsylvania*, September 17, 1897), at a special meeting of the Bucks County Historical Society at Doylestown, October 7, 1897, and in *Tools of the Nationmaker*, published by the Bucks County Historical Society, Alfred Paschall, Doylestown, 1897, under the numbers 103, 633, 689, 726.

1. Leaflet 8¼ inches long by 6¾ inches broad. Name. Words, *Dieses Vorschrifften Buchlein Gehoret Margretha Wismerin Schreib Schuler in der Birchenseher Schule* (now Blooming Glen). *Vorgeschrieben der October 4te, 1781.* Above a short prayer, surrounded with admonitions to diligence. In rectangle, formed of ornate foliated borders, are three feathered crowns and two angels holding tulips and blowing trumpets. Tulip stalks spring from hearts. Colors, blue, green, red, yellow and black. Probably made in the last century by Jacob Overholt, teacher in a log schoolhouse near Deep Run, Bucks county, Pa. Presented to the writer by his descendant, David Landis, of Plumsteadville.

2. Title-page to church song book (*Lieder Buch*, printed in Germantown, Michael Villmeyer, 1811). Name, Susanna Fretz, upon heart, from which springs a tree with the conventional tulips. Deep beaded bordering, 1814. Colors, red, yellow, brown and black, red predominant.

3. Title-page to manuscript song book. Name, Susanna Fretz (spelled *Fretzin* for feminine) in red circle, with date, 1810. Stalks, with black leaves and conventional tulip to right and left. Foliated border with red leaves on black and yellow ground.

4. Illuminated card on blank page of same hymn book. Above name, Susanna Fretzin, heart, from which rises conventional tulip. In possession of Henry W. Gross, Doylestown.

5. Title-page to manuscript hymn book. Name, Joseph Gross; illuminated letters, foliated capitals. Date, April 20, 1830. Double tulips in foliate border on yellow ground.

6. Title-page to manuscript hymn book. Name, Sarah *Wismer*. Foliated capitals, conventional flowers on heavy stalks. Date, 1827. Colors, yellow, red, brown and blue.

7. Title-page to ditto. Name, Elizabeth Nesch, spelled *Neschin;* with words, *Dieses Sing-Noten Buchlein Gehoret Mir. Sing Schuler in der Bedminster Schule. Geschrieben, September 6ten, im Jahr, 1799.* Three tulips. In possession of Joseph N. Gross, Doylestown.

8. Title-page to similar book, with tulips floriated capitals, and name, Stauffer. In possession of Isaac J. Stover, of New Britain.

C. Rewards of Merit on Loose Leaflets.

About a Foot Long by Eight Inches Broad.

First there is a text of Scripture, with elaborately illuminated characters, and done in many colored inks, under which a bar of music may set the tune to a German hymn, engrossed in many verses below. From this rich, floriated text, with its adorned and highly colored borderings, emerge birds, twining stalks growing from symbolic hearts bearing tulips, or angels blowing trumpets. Examples are:

1. Leaflet, 13¼ inches long by 8⅜ inches wide, with floriated text, *Allda Kreuzigten Sie Ihn.*, etc., etc., nineteenth chapter of John, eighteenth verse,

Luther's translation (see Plate V). Above, single bar of music, with red lines heading hymn and six verses beginning, *O fröliche Stunden, O herrliche Zeit.* Under this the alphabet in common German handwriting, capitals and small letters, with Arabic numerals up to a hundred. Below, to the left, transverse rhymed admonition in red and black ink, beginning *Ach lieber Mensch.* Two birds are set upon the text of the hymn. The capital letters are elaborately illuminated and surrounded with scrolls. The bordering to the left is colored with a design. In the possession of Henry W. Gross, Doylestown. Date probably from 1760 to 1790.

2. Similar leaflet. Text, one hundred and third Psalm, verses nine and thirteen, in German. Hymn and six verses. Alphabets, numerals and admonition arranged as before. Elaborately illuminated capitals and colored borderings, birds, scrolls and tulips. Colors, red, brown, blue, green yellow and black. Name Christian Gross, in rectangle. Date probably about 1760. In possession of Isaac Gross, of Bedminster.

3, 4. Two similar leaflets, closely resembling each other. Text, Philippians i. 23. Hymn in five verses. Admonition, alphabets and numerals omitted. Capitals more elaborately floriated than before. Conventional leaves, flowers, tulips and birds. Colors, red, blue, green, yellow and black. Ornate borderings with heart pattern. Name, Isaac Gross, on corner of one specimen. Made by Isaac Gross, of Bedminster, related to the owner, born 1807, died 1895. Date about 1840, or earlier. In the possession of Henry K. Gross, of Plumsteadville.

5. Leaflet, slightly smaller (see Plate VII), with hymn or sacred verse in six rhymed lines, beginning *Jesus soll mein Jesus bleiben*, intertwined with numerous leaves bearing flowers. Elaborately scrolled capitals and four birds over the name of the maker, Isaac Gross, January 10, 1830. Colors, green, red, brown, blue and black. In possession of Henry K. Gross, of Plumsteadville.

6. Leaflet, 11¾ inches long by 7¾ inches broad. Text, Proverbs xiii. 7. Below this, a prayer on the theme of poverty. Capitals set in rectangles filled with pen hatchings. Colors, red and black, with a little green. Date about 1760 or earlier. In possession (1897) of Isaac Gross, of Bedminster.

7. Leaflet, 13 inches long by 8 inches wide. Pious rhyme of admonition to children, beginning *Die Kinder Lieb ist Wunderlich*, with elaborately illuminated capitals, scrolls, leaves, a bird and several tulips. A separate admonition in small ovate enclosure to the right, colored borders with alphabet below. Colors, blue, red, yellow, green, brown and black. In possession of John Walters Chalfont.

D. Book Marks.

Sometimes consisting of such designs as tulips springing from hearts, conventionalized trees, or religious symbols. Examples are :

1. Leaflet, 6½ inches long by 3¾ inches wide. Two conventional trees with red stalks, and lanceolate green leaves. Border, yellow and red. No writing. In possession of Henry K. Gross, Plumsteadville. Date, about 1830.

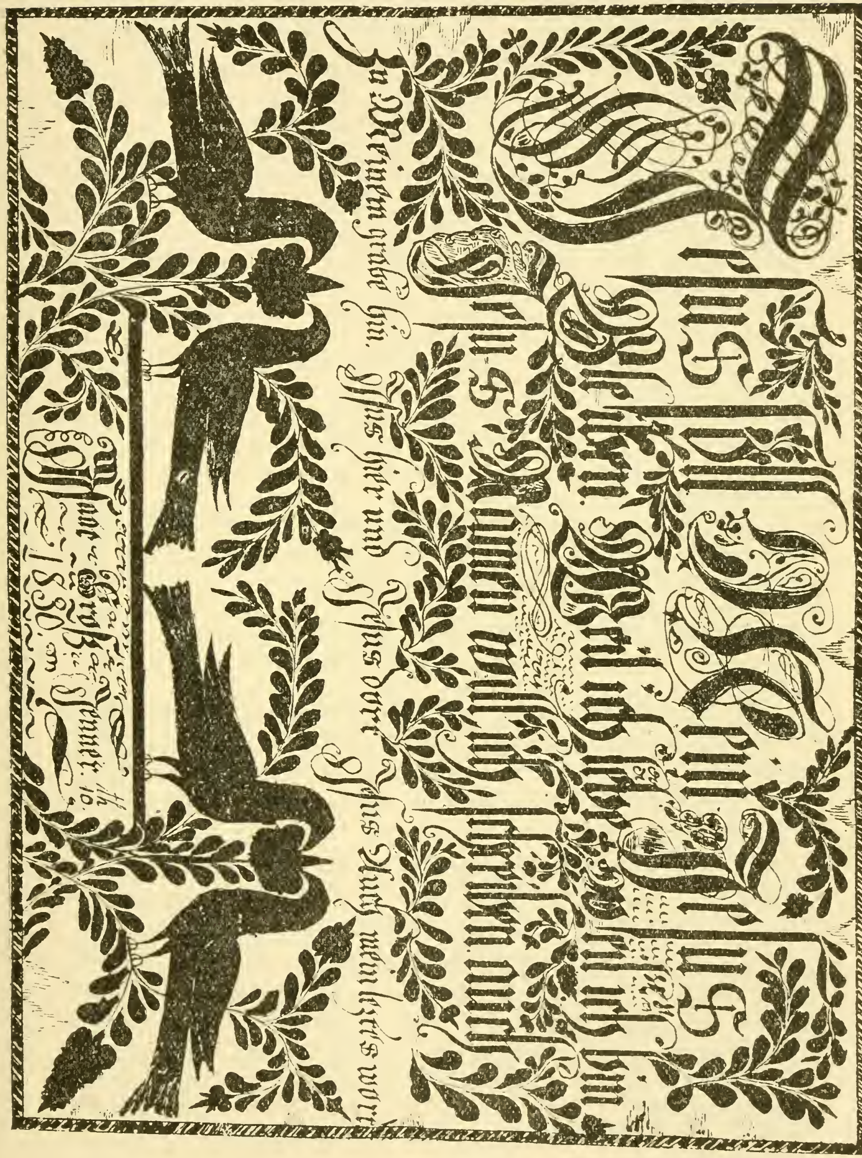


Plate VII. Illuminated leaflet with hymn, and date, 1830. In possession of Henry K. Gross, of Plumsteadville.

2. Conventional bird, the pelican (a mediæval church symbol emblematic of the Redemption), standing upon bracket protruding from urn-shaped nest, tears its breast with its beak (see Plate VIII). Three dotted red lines lead from the wound to the outstretched mouths of three eel-shaped young birds uplifting their bodies from the nest. Colors, red, yellow, green and black. No writing. In possession of Henry K. Gross, of Plumsteadville. Date, about 1830.

3. Leaflet, 7⅞ inches long by 6¼ inches broad. No writing. Two tulips with other flowers sprout from heavy red stalks. Illuminated borders. Colors, red, yellow, brown, green, blue and black. Date, 1820. Made by Isaac Gross, died 1895. In possession of Henry K. Gross, of Plumsteadville.

4. Small leaflet, 4 inches long by 2 inches wide. Stalk bearing large tulip. Flower rises from centre of the heart. Name, Susanna Fretzin. Illuminated border. Colors, red, green, yellow, brown and black. Date probably about 1810. Property of Henry W. Gross, of Doylestown.

5. Unfinished leaflet, 7 inches long by 4⅝ inches wide. Words, *Diese Bibel ist gekauft worden im Jahr unsers Herrn 1830, den 25th December und gehoret mier, Isaac Gross, $10.* Abundant leafage springing from a heart with flowers and tulips done in red outline. Brush work just begun. Ornamental borderings. Colors, blue, black, yellow, red and olive. In possession of Henry K. Gross, Plumsteadville.

6. Leaflet, about 9 inches long by 6½ inches broad, with angels and illuminated writing done by teacher of Pebble Hill German School about 1800. In possession of Mrs. Levi Garner, Doylestown.

E. Taufscheine or Baptismal Certificates with Marriage and Death Registers in Bibles.

The German custom of preserving baptismal certificates, though wanting the force of legal compulsion, after crossing the Atlantic, survived until recent years in parts of Pennsylvanian Germany. Not practiced by the Mennonites, owing to their rejection of the doctrine of infant baptism, it prevailed extensively among Lutherans in northern Bucks and Lehigh counties, where however since about 1840 printed *Taufscheine*, gaudily colored, took the place of the old documents illuminated by hand.

Three of the printed certificates (giving the date of the individual's birth on a colored sheet adorned with hearts, wreaths, four birds, and angels blowing cornets, published by Johann Ritter, Reading, 1845, and in Allentown in 1848) were seen by the writer in October, 1897, in possession of Philip Flores, of Dillingersville, Lehigh county.

Examples of the old illuminated *Taufscheine* are:

1. Round leaflet, 7¼ inches in diameter, surrounded by a round band, spotted in red, the latter fringed on both sides with yellow and red scrolls. Text, in black, *Anna Maria ist von christliche Lutherische Eltern im Jahr Unsers*

Herrn Jesu Christi 1782 den 30. Jenner in Grossschwam Taunschip, Bocks Counti, Geboren, etc., giving name of minister, father, mother and witnesses. Presented by Mr. S. W. Boyer, of Spinnerstown, to the Bucks County Historical Society.

2. Leaflet, 15 inches long by 12½ broad. Text in scalloped circle inscribed with legend, *Wer da glaubt und getauft wird, der wird selig werden. Wer ihn nicht glaubt der wird verdamet werden.* The border is adorned with two large flower stalks, a singing bird and a swan, and two gaudy flying female figures with puffed hair and rosy cheeks, bearing flowers. Another singing bird adorns a small circlet, and upon a heart is inscribed the motto, *Dis Herz mein soll dir allein O lieber Jesu sein.* The baptismal inscription is in plain black Gothic text, *Diese beide Ehegatten als Johannes Erdman und Seine Ehefrau Sara, Eine Geborene Pitzin, Lutherische Religion, ist Einen Sohn Zur Welt Geboren als Heinrich, ist Geboren im Jahr Unseres Herrn Jesu Christi 1792 d. 29. Jany um 6 Uhr Abends in Saccon Taunschip Northhampton Counti im Staat Pensylvanien*, giving name of pastor and of witnesses. Colors red, brown, green and yelow. In possession of the Bucks County Historical Society. Given by Oliver H. Erdman, Steinsburg, Bucks county, Pennsylvania.

3 and 4. Two leaflets in style like the above. Certificates of Peter Floers, 1792, and Elizabeth Wetzel, 1804. Flying woman, birds, swans and hearts, floridly executed as above. On one of the hearts is the legend, *Dis Herz mein soll dir allein O lieber Jesu sein.* In possession of Philip Flores, Dillingersville.

5. Leaflet about 15 inches long by 12 wide, containing text in an ornamented square, with heavy border adorned with conventional flowers and tulips, and four hearts containing legends (see Plate IX). Colors brown, red, yellow, green and blue. A certificate in black German Gothic text, translated, says that "Samuel Roeder was born of Christian and married parents in Herford township, Berks county, in Pennsylvania, on May 8, in the year 1779, and was given his Christian name by the minister, Theobold Sahwer, in the Christian Church in Nugoschenhoben," giving witnesses, etc. Deposited in the Museum of the Bucks County Historical Society by Nathan Roeder, of Spinnerstown, Bucks county, Pennsylvania.

The marriage and death registers in Bibles are plainly executed as compared with the other specimens, and it seems that the practice of engrossing these latter lasted much later than the other phases of the art, and still continues (1897) among German families in upper Bucks county. More than two colors, red or purple and black, are rarely used. The elaborate scrolling, the leaves, hearts, birds and tulips, have disappeared. Examples are:

1. Register bound in Lutheran Bible of Mrs. Levi Garner, of Doylestown.

2. Similar register, in purple ink, made about 1890, in Bible of Mr. Elmer E. Funk, of Doylestown.

3. Loose register from Bible of the Hendricks' family near Perkasie, showing late survival of the tulip design. Words, *Sarah Hendricks ist geboren den iten September im Jahr 1851.* Capitals decorated in inferior style with leaves and

three tulips. Colors, very little red, blue and yellow. Probably made in Bedminster. In possession of J. Freeman Hendricks, Doylestown.

It appeared upon inquiry that the art of *Fractur* was easily traceable to Germany, where, according to information received from foreign-born citizens of the United States living in Philadelphia and Bucks county, it had been taught without religious significance (generally in black, rarely in colors, save to special scholars, and sometimes, if desired, in Nassau with the reed pen of the monks), until about the year 1850, at public schools in Saxony, Bavaria, Hanover, Hesse and Nassau.

If the existence of Fractur in Pennsylvania had been adequately noticed before, its evidences are so interesting that it might well be described again, but we learn that it has been little more than casually alluded to by any writer. Yet it illustrates the relation of Germany to the United States at one of its most interesting points. It recalls the fact that while the English reformation was hostile to artistic impulses, the German reformers were not always unfriendly to them. In this case, at least, they held fast to one of the most beautiful products of mediæval fancy. Here is a contribution to American character at the beginning, for which we owe nothing to New England and the Puritans. Fractur did not come over in the *Mayflower*, nor did it flourish among the associates of those New England reformers who, at the siege of Louisburg, are said to have attacked the adornments of the captured cathedral with axes. As in the case of the Pennsylvanian earthenware of the last century, glazed in several colors and decorated with tulips or the lotus; as with the Durham stove plates of 1750, adorned by Germans with flaming hearts, tulips and designs of Adam and Eve, Potiphar's wife, and the Dance of Death, we see that we are dealing with a reflection of the artistic instinct of the Middle Ages, directed upon us from the valley of the Rhine. The fresher from Germany the better the work. But by degrees the iron caster forgets his trans-Atlantic inheritance of taste. A lack of skill finally overtakes the potter after years spent under sterner and more material conditions. First, the German mottoes are abandoned upon the plate and jar. By degrees the colors grow less varied and the designs weaker. Then the toys and whistles in the shape of birds, fish and animals, are forgotten with recipes for glaze. At last only the yellow tints of the pie-dish remain. So, too, the hand of the master of Fractur looses its cunning and the fading art ceases to exist in the memory of a generation yet living.

The establishment of the English school system in Bucks county in 1854[1] necessarily resulted in the suppression of the previously existing German schools. Hence that date after which the latter, sustained by private subscription, lingered on for a time, reasonably marks the end of Fractur in a region where at least two aged masters of the craft still survive in the person of Jacob Gross, of New Britain, and John H. Detweiler, of Perkasie.

A study of these fugitive examples of a venerated handwriting leads the investigator by sure steps from the Germany of Pennsylvania to the valley of the Rhine, from the backwoods schoolhouse to the mediæval cloister. In the fading leaflets we recognize prototypes of the glowing hand-made volumes that illuminated learning in the Middle Ages and still glorify the libraries of the Old World. From the paint-box of Bedminster to the priceless book which at Venice is shown to the delighted visitor as the handiwork of Hans Memling, we are led by a chain of intimately related facts. With strange sensations, we rescue from the Pennsylvanian garret evidence indisputable of the passing away in the New World of one of the fairest arts of the cloister, which, meeting its death-blow at the invention of printing, crossed the Atlantic to linger among the pious descendants of the German reformers until recent years.

Stated Meeting, October 1, 1897.

Mr. INGHAM in the Chair.

Present, 11 members.

Donations to the Library and Cabinet were reported, and thanks were ordered for them.

[1] A German school sustained by a private subscription was taught by the Mennonite Samuel Musselman, in Swartley's schoolhouse, at the lower end of Hilltown, Bucks county, Pa., about 1866. Information of Mr. J. F. Hendricks Doylestown. Another, the last in Bucks county, existed, under the tuition of Mr. Meyers, of Deep Run, at the old Mennonite Schoolhouse near the meeting house at Deep Run, Bucks county, Pa., in the winters of 1895–96 and 1896–97. At the latter school where a pair of the time-honored leathern spectacles (*Bocksbrille* or *Schulbrille*) now in possession of the Bucks County Historical Society, were used to punish children in 1897, the ceiling rafters are still inscribed with bars of music written in chalk.

The Committee on Mr. Van Denburgh's paper recommended its publication in the *Transactions*, and it was so ordered.

The meeting was adjourned by the presiding officer.

Special Meeting, October 11, 1897.

Vice-President PEPPER in the Chair.

Present, 41 members.

The special meeting was called by the President for the reception of communications on subjects of science.

Lord Kelvin was presented to the Chair, and took his seat in the Society.

Communications were made by Prof. Heilprin on "The Absence of Glacial Action in Northern Africa."

By Prof. G. F. Barker, on "The Constitution of Matter."

By Prof. Doolittle, on "Latitude Variation."

By Dr. Kennelly, on "A Speculation upon the Nature of Cathode Rays."

By Dr. D. G. Brinton, on "The Measurement of Thought as Function."

The meeting was adjourned by the Chair.

THE VARIATION OF TERRESTRIAL LATITUDE.

BY C. L. DOOLITTLE.

(*Read October 11, 1897.*)

As the distinguished scientist with whose presence we are favored this evening has on various public occasions shown a deep interest in the problem of latitude variation, it has occurred to me that a brief communication on this subject might not be out of place on this occasion. In this connection I shall speak of the work which we are doing at our newly erected Observatory of the University of Pennsylvania. As the audience is not composed exclusively of professional astronomers, it will perhaps be as well to give a brief statement in explanation of the problem.

The idea of possible variations in the latitude of points on the earth's surface is by no means a new one. It is, in fact, as old as Ptolemy. At various times, from that day to this, apparent changes of this character have renewed the interest of scientific men in this subject. It is probably superfluous to say that these supposed changes of latitude were almost exclusively due to imperfect methods of observation and to want of knowledge of various theoretical matters now well understood, that with improvements in instruments, with more perfect knowledge of the effect of refraction, with the discovery of aberration and nutation these supposed changes for the most part disappeared.

More than a hundred years ago, the illustrious Euler gave to this subject something like a scientific basis. In the development of the law of rotation of a rigid body, for which we are indebted to him, it was shown that a body like the earth, supposed to be perfectly rigid and in form an ellipsoid of revolution, unless originally started in its diurnal rotation about an axis exactly coinciding with the axis of figure, would have in addition to this diurnal rotation another motion. Suppose the original axis of rotation to make a small angle with the axis of figure. It was shown that this axis of rotation would itself revolve about the axis of figure, describing the surface of a cone, the angle between the two axes remaining unchanged. The period of this rotation depends upon the principal moments of inertia of the earth or upon their relation to each other, which may be found from the observed values of the constants of precession and nutation. The resulting period proves to be about 305 days, or ten months.

If, therefore, this period has a real existence, that is, if the axes of rotation and figure do not exactly coincide, it will, according to this theory, be shown by a periodic increase and diminution of all terrestrial latitudes in a corresponding period. Such a change was not found, though sought for by many investigators. In fact, the apparent perfection of the theory probably retarded the true development of the matter for several years. However, about ten or fifteen years ago, a number of apparent changes of latitude, found from various series of observations made at different places and by different methods, began to awaken a widespread interest in the subject. That the changes were real admitted of but little doubt. It was equally obvious that they could not be fitted into the ten-month period of Euler.

Finally, Mr. Seth C. Chandler, by a most laborious investigation, embracing an analysis of many thousands of observations, extending over a hundred and fifty years, succeeded in solving the mystery, at least in so far as existing evidence can solve it. The result shows that the earth's axis of rotation moves about the axis of figure not in one simple period of ten months, but in two periods of twelve and fourteen months respectively, with perhaps a third of several years. The combination of these motions results in a somewhat complicated curve. If we suppose circles drawn about the north and south poles of the earth having diameters of about fifty feet, the extremities of the axis of rotation will always be found within these circles.

For the purpose of perfecting our knowledge of these motions, for obtaining data for a correct explanation of the same from a theoretical standpoint, very accurate and carefully executed series of latitude observations at different points are necessary. It is such a series we have undertaken at the Flower Observatory. This series is a continuation as far as may be of that which was kept up for several years at South Bethlehem.

In this work the instrument employed is the Zenith Telescope. The stars observed are arranged in groups so selected that the errors in the positions of the stars are almost completely eliminated in so far as they effect the apparent change of latitude. Regular observation at our Observatory for this purpose was begun October 1, 1896. Since this date observations have been made on nearly every favorable night. Two series constitute a complete night's work, the first in the early evening soon after dark, the second in the morning before sunrise. Each series embraces ten pairs of stars, requiring about two hours of actual observation. As will be seen, the work is laborious. This with the necessary numerical computation might very well be regarded as sufficient employment for one person.

Some 1700 observations, extending from 1896, October 1, to 1897, August 26, have been reduced so that we can form some judgment of the results obtained and of the character of the work.

We find a pretty satisfactory agreement with the theoretical results as given by Chandler's formula, the range of variation being about 0″.4, as indicated both by observation and theory. The phase, however, is a little more discordant, that is the times of maxima and minima, as shown by observation, do not quite agree with those indicated by theory. However, the amount of material is not yet sufficiently great to warrant any sweeping conclusions.

As to the quality of the work, the probable error of a single observed latitude is found to be 0″.14. This is derived from the mean of everything, whether the conditions were favorable or otherwise. It does not take into account the errors of the star places used, but is simply what is sometimes called the internal probable error.

The probable error of the mean of one series of ten observations will be something over ″.04. Nevertheless we find in comparing the results from consecutive evenings ranges sometimes as great as 0″.5, or say twelve times the probable error. Such variations from evening to evening are not peculiar to our own work, but are found in every extensive series which I have examined. In some cases the range has been found as great as 0″.7. The cause of these discrepancies is at present very much of a mystery. They are presumably due in great part to atmospheric causes, producing anomalous refraction phenomena. It is apparently a very difficult matter to deal with, but unless means can be found for doing so it would appear that we have about reached the limit of accuracy attainable in this class of work.

The instances before mentioned are the extreme ones. The fluctuations from night to night are usually far within the amounts mentioned. Usually it will be difficult to determine whether the variation is a real one or simply represents the error of observation. An unusually favorable opportunity for investigating this matter was furnished by the work of Marcuse, of Berlin, and Preston, of the U. S. Coast Survey, who, in 1891–92, carried on similar series of observations at Waikiki, in observatories separated by only a few feet. A comparison of the results with reference to this point was made by Marcuse, but the result was not very decisive. In a general way the number of cases of agreement in the direction of the variation was about twice as great as that of disagreement. One case in particular was very interesting, where for nine consecutive days the latitudes given by the two different observers always varied alike. In other cases, however, for many consecutive days no agreement between the two series is apparent. It is greatly to be desired that this matter should receive a thorough investigation, but the method by which the problem may be successfully attacked is not obvious.

THE MEASUREMENT OF THOUGHT AS FUNCTION.

BY DANIEL G. BRINTON, M.D.

(Read October 11, 1897.)

I can best introduce what I have to say by a quotation from the address of Vice-President McGee before the late meeting of the American Association at Detroit. He refers in it to a distinguished member of our own Society who, I am glad to see, is with us to-night; and the words I am about to quote are of such a tenor that that they cannot be otherwise than agreeable. Mr. McGee said:

"Less than a quarter of a century ago Barker was deemed bold unto recklessness for undertaking to correlate vital and physical forces, and many heads were shaken doubtfully when, in his presidential address before the American Association at Boston in 1880, the same brilliant experimentalist argued from the application of Mosso's plethysmograph that mental force also may be weighed and measured, so that it must be regarded as interconvertible with other forms of energy; yet less than half a generation of organic chemistry has established these revolutionary propositions beyond peradventure" (*The Science of Humanity*, by W. J. McGee, Vice-Pres., Address before Section H, at Detroit, 1897).

These words must have been intended by their writer to have important limitations. If taken in their ordinary sense they would convey a very erroneous idea of the achievements of physical and chemical science.

It is quite true that the action of thinking is in one sense a function of the brain, and is accompanied by cell destruction, by increased temperature and by the increased elimination of inorganic matter through the secretory organs. For this reason it was said by one of the older physiologists that "without phosphorus there is no thought." In a somewhat similar manner others have undertaken to demonstrate that thought is merely a mechanical process, and, indeed, a logical machine was invented by Jevons which could carry out a proposition from major premise to conclusion. From another aspect the late Dr. Post, of Bremen, used to maintain that "we do not think, but thinking goes on within us;" just like any other involuntary function of our bodies.

All such statements must be understood to apply only to certain concomitant phenomena of thought; but by no proper use of words can such phenomena be taken as the measure of thought itself. This measure eludes all chemical and physical research, and can in no way be calculated by mechanical formulas. The worth of the thought bears no relation whatever to the physical changes of temperature and cell activity concerned in its production. Mental force cannot be weighed and measured, nor is it convertible by any means known to us into other forms of energy.

The value of thought and the measure of mental force is, as has already been intimated by our distinguished guest this evening, the *truth* of the thought, the verity of the proposition. To quote from Shakespeare, "A tale told by an idiot, full of sound and fury, signifying nothing," may cost that poor idiot's brain just as much cell-destruction and increased temperature as did the composition of *Macbeth* to the great dramatist. A false or a worthless thought involves just as many changes as a true and valuable one. The brain of the savage is often as active, functionally, as that of the devotee to science; but how different the value of the results! As a physical stimulus affecting the lives of organic beings, the truth of thought is the only measure of the power of thought.

A striking confirmation of the views I am urging is the undoubted fact that the greatest conquests of thought, its most valuable productions, arise when the functional activity of the brain is at a low ebb. They are the fruits of what is called "unconscious cerebration;" or by its more modern name, "subliminal consciousness." The greatest inventions, the solutions of the most difficult problems in mathematics, the most marvelous inspirations of genius in art, have reached their finders in such passive moments. How wide of the mark, therefore, is it to expect to measure mind by units of matter! There is absolutely no common measure between them, and nothing in modern chemical or physical science weakens this ancient doctrine.

If what I have said is true as respects the facts of science, how much less capable are material weights and measures of appraising those spiritual forces, whose potency lies in exalting the character of the individual, and in elevating the tone of national life, and on which alone we must depend for the real progress of the human race?

Let me, in conclusion, present this last point in the words of one of the noblest and most gifted women of our English-speaking race—Elizabeth Barrett Browning:

> "If we tread the deeps of ocean, if we strike the stars in rising,
> If we wrap the globe intensely in one hot electric breath—
> 'Tis but power within our tether—no new spirit-power comprising,
> And we are not greater men in life, nor bolder men in death."

Stated Meeting, October 15, 1897.

President FRALEY in the Chair.

Present, 41 members.

Mr. Stewart Culin, a newly elected member, was presented to the Chair, and took his seat in the Society.

Donations to the Library were reported, and thanks were ordered for them.

The death was announced of Prof. Alfred L. O. Cloiseaux, of Paris, France, a member of the Society.

Mr. Rosengarten was appointed to prepare the obituary notice of Mr. J. Sergeant Price.

Nominations Nos. 1380, 1389 to 1398, 1400, 1402 to 1409, 1418, 1423 to 1431 were read and spoken to, and Tellers were appointed to conduct the election for members, who reported the following as having been elected members:

2323. Clarence B. Moore, Philadelphia.

2324. James Biddle Leonard, Philadelphia.

2325. George Vaux, Jr., Philadelphia.

2326. James Seguin DeBenneville, Philadelphia.

2327. Richard H. Sanders, Philadelphia.

2328. William Tatham, Philadelphia.

2329. Gregory B. Keen, Philadelphia, Librarian of the University of Pennsylvania.

2330. George Wallace Melville, Washington, Commodore and Chief Engineer U. S. N.

2331. Charles D. Walcott, Washington, Director of the U. S. Geological Survey.

2332. Edward R. Squibb, M.D., Brooklyn.

2333. George Wharton Pepper, Philadelphia.

2334. Hon. Wayne MacVeagh, Philadelphia.

2335. John C. Smock, Trenton, State Geologist of New Jersey.

2336. Hon. Grover Cleveland, Princeton.

2337. Hon. Thomas F. Bayard, Wilmington, Del.

2338. William Libbey, Princeton, Professor of Physical Geography, Princeton University.

2339. Alfred T. Mahan, Captain U. S. Navy.

2340. Frank Morley, Haverford, Professor of Pure Mathematics, Haverford College, Pa.

2341. Woodrow Wilson, Princeton, Professor of Jurisprudence, Princeton University.

2342. George A. Piersol, M.D., Philadelphia, Professor of Anatomy, University of Pennsylvania.

2343. Lightner Witmer, Ph.D., Philadelphia, Assistant Professor of Experimental Psychology, University of Pennsylvania.

2344. Rudolfo Lanciani, Rome.

2345. James Mark Baldwin, Ph.D., Princeton, Professor of Psychology, Princeton University.

2346. Henry M. Howe, New York.

2347. Edward H. Williams, Bethlehem.

2348. H. Morse Stephens, Ithaca, Professor of Modern History, Cornell University.

2349. Charles R. Hildeburn, Philadelphia.

2350. Percival Lowell, Boston, Director of the Lowell Observatory, Flagstaff, Ariz.

2351. A. Donaldson Smith, M.D., Philadelphia.

The rough minutes were read, and the Society was adjourned by the presiding officer.

Special Meeting, October 29, 1897.

President FRALEY in the Chair.

Present, 100 members.

The special meeting was held for the reception of communications on subjects of science.

Dr. Fridtjof Nansen, a recently elected member, was presented to the Chair, and took his seat.

Dr. Nansen presented a communication on "Some Results of the Norwegian Polar Expedition, 1893–96," which was discussed by Commodore Melville, Prof. Abbè, Prof. Heilprin and Mr. Amos Bonsall.

The reading of the rough minutes was dispensed with, and the Society was adjourned by the President.

SOME RESULTS OF THE NORWEGIAN POLAR EXPEDITION, 1893–96.

BY DR. FRIDTJOF NANSEN.

(*Read October 29, 1897.*)

Mr. President, Ladies and Gentlemen :—

First of all, I beg to thank you most heartily for the great honor the Society has shown me and the cordial welcome you have given me.

It is with some hesitation that I come to discuss the results of the exploration from which I returned last year. The material I brought back is not by far worked out, and it will take years before it can be properly studied, and before this is done perhaps I ought not to talk much about the results for fear of giving you wrong ideas. But in the meantime I would like to point out a few of the more important points in our discovery, and I propose to begin with the geographical discoveries.

The whole plan of the expedition was based on a theory concerning the currents, about which we knew very little before. I thought, for various reasons, that there was a constant drift of the ice across the north polar region. I would especially refer here to some relics from the American ship Jeannette, which were found on the southwest coast of Greenland three years after the Jeannette was crushed and sank at a point northeast of the Siberian Islands. The question arose, How could these relics have come to the coast of Greenland? The only feasible explanation, in my opinion, was that first proposed by Prof. Mohn. The relics must have been drifted straight across the polar region to the north of Franz-Josef Land and Spitzbergen, then must have come southward by the east coast of Greenland, thence around Cape Farewell and northward along the southwest coast. (Dr. Nansen then taking his position by a chart pointed out the supposed course of the relics.) Here is a map of the polar region. The Jeannette was beset in the ice near the Wrangel Island, which was then believed to be a large land, extending northward. She was drifting for nearly two years in a northwesterly direction to a point about here (indicating), where she was crushed by the ice pressure and sunk; and, as you know, the gallant crew of that vessel had a desperate struggle to reach inhabited parts, and it is unnecessary here to touch upon the sad fate of most of them.

Three years later some relics were found down here (pointing to the southwest coast of Greenland) and the only explanation was that they must have drifted this way down (indicating). There was, however, other evidence that made me believe still more firmly in this constant drift across, and that was especially that drift timber is found on the Greenland coast, on the Spitzbergen coast and on various other lands in the Arctic regions, and that most of this drift timber proves, on examination, to have come from Siberia. The only explanation, in my opinion, is that this drift timber must have been carried to these shores by the floe-ice across the polar sea somewhere near the pole; although I must say that this opinion is against that of most authorities.

As a further proof I will mention a third evidence of great importance, and that was some mud that I found on the ice floes on the east coast of Greenland. This map does not show it, but Iceland would be about here (indicating) and there is a strait between Iceland and Greenland. In this strait I collected, in 1888, some specimens of mud, and by a microscopic examination of this mud it was found to contain many diatoms never found anywhere else in the world except near Bering's Strait. Some specimens collected by the Swedish Vega expedition were examined by Prof. Cleve, who also examined my mud. He said "that the diatoms contained in the two samples of mud are perfectly alike, and are totally different from those contained in all other samples in the whole world." I thought it could not be explained in any other way but that there must be some connection between the two places, the ice carrying the mud to where this mud was found across the polar sea.

There were also other evidences that made me believe in this drift current. If this drift really existed, I thought it a simple thing to go with it; to build a ship strong enough to stand the pressure, push her into the ice and let her be carried along with it just as the Jeannette was. And that is what the expedition accomplished. As the expedition was therefore undertaken with the intention to drift with the ice, we could not expect that we would discover many new lands. My hope was to keep clear of the land, as that would stop our drifting and perhaps oblige us to leave the ship and travel over the ice. We were fortunate enough not to meet any land. We found only one vast extended sea in the north, which was very much deeper than we had expected.

Before we set out a good many authorities said that the reason why such a drift was impossible was because we would meet with much land in the north, and that the sea was shallow. So far as we knew it was shallow north of Asia. The greatest depth found by the Jeannette expedition was eighty fathoms. I also believed that this sea might be pretty shallow, but seeing that there was a deep sea north between Greenland and Spitzbergen, a sea extending up to 2600 fathoms in depth, the northern limits of which had not been found, and seeing at the same time that the depth increased with the progress of the Jeannette expedition, as it was carried to the north and east, I said it looks as though there should be some connection between the deepening of the sea to the north of where the Jeannette expedition met with disaster and this deep sea east of Greenland. I thought there might be some narrow channel or trough of deep sea across the polar region.

Great was my astonishment when I found a great depth as soon as we got north of the New Siberian Islands. All the way north from the Siberian coast there was a very shallow sea, only twenty or thirty fathoms deep, until at a certain point the depth suddenly increased and we could not reach the bottom with all the lines we had on board. We had to make new line and at last we found the bottom at about 2000 fathoms, and we found the same deep basin along the whole route of the Fram across the polar region.

The question then arises, Of what extent is this sea? I did not find anywhere any indication that the sea grows shallow. We see it stretching from the south northward into the unknown. We also see it stretching eastward to the region north of the New Siberian Islands and we might expect it to extend much further eastward. When we look at the deep seas on the rest of the globe's surface we do not find anywhere such a long, narrow extension of very deep seas; and, therefore, the probability is that this sea is much broader than we had an opportunity of ascertaining. We may therefore say that we have established the fact that a great part of the polar region is an extended, deep sea, instead of the shallow sea that we believed in before. I think there cannot be much doubt that the whole of the polar region lying on the Asiatic and European side of the pole is one extended sea.

For this belief we have several reasons. First, as I have just mentioned, the depth of the polar sea indicates some extension of the sea to the north of the Fram's course. But there are other evidences. It is evident that ice drifting in a sea where there is land in the neighborhood will be stopped in its drift as soon as it drifts in the direction of this land. Now, however, if there had been land anywhere in the neighborhood of our route it is evident that if the ice happened to drift in that direction it would have been stopped at once. But we never saw anything of the kind. The ice seemed to drift readily in almost every direction as the wind commenced to blow in that direction. The only direction in which the ice seemed to drift slowly and with some difficulty was backward in the direction from which we had come, and there we knew there was nothing but open sea. Very easily, say as soon as the southerly wind began to blow, the ice drifted toward the north, consequently there was no possibility of land being found anywhere near us in that direction.

There is another evidence which is even stronger, and that is the amount of floe-ice or polar ice floating southward through the channel between Spitzbergen and Greenland and especially along the eastern coast of Greenland.

When you look at the route of the Fram you see the drift going in this direction (indicating). She drifted to about this point (indicating), and then began to work herself out of the ice by forcing herself forward with the help of her steam engine. If she had not done this she would, of course, have been drifted further in the same direction, and then she would as you see have been drifted southward along the east coast of Greenland, and might have drifted in that direction for a year more.

Thus you see there would have been a broad belt of drift ice drifting southward between the Fram and the coast itself. It is evident that this ice must have traveled by a route similar to that of the Fram, but that route had been to the north of the Fram's. All this ice (indicating) must therefore come from an extended sea lying to the north of our route, and consequently there cannot be any land in that region stopping the drift. Thus, we have good reason to believe that the whole extent of this region on the European and Asiatic side of the pole is nothing but sea, perhaps with some small islands of no importance. In my opinion the pole itself is situated in the same extended deep sea.

This distribution of the land and water on the European side is, I think, the most important feature of the geographical discoveries made by us on the expedition. There might, of course, be found land on the American side of the polar region. It is not probable that we should just now happen to have found the northern limit of land on this side. Much still remains to be done by future expeditions in geographical exploration.

Before leaving the subject of geographical discoveries, I will briefly mention the extent of Franz-Josef Land. You know that the group of islands situated to the east of Spitzbergen, called Franz-Josef Land, was discovered by the Austrian Tegethofft expedition in 1872–4. The expedition had only explored the southern coast of this land and made a dash northward through a narrow channel which was called Austria Sound. Afterward the English explorer Leigh-Smith came two summers to this land and discovered the more western part of its coast. The last time he came his ship was crushed and he spent the winter there and came back in boats the next year. The northern extension of this land was not at all known, and therefore it was believed by some authorities that this land was only the southern coast of a big continent extending poleward. I did not believe this; I believed that Franz-Josef Land was only a group of islands. Now with our discoveries and those of the English Jackson-Harmsworth expedition it is an established fact that Franz-Josef Land is a group of very small islands. We came southward here (indicating) and we saw there was no land of importance to the north. The island we first met with was situated in 81° 38″ north latitude. We traveled along the north coast here (indicating), and now the English expedition has this spring traveled along the northwest coast of these islands here (indicating) and found that there was nothing but a comparatively small island which approximates the most western point of this map. Consequently we know pretty nearly the whole extent of Franz-Josef Land. We want to know its extent toward the east and it is hoped that some expedition not far in the future will settle that.

While I have mentioned the geographical results of the expedition, I should mention the geological results also, but will not detain you long with them. There is one important geological discovery which we made, and that is the evidence we found of a glacial epoch in Siberia. As you certainly know, the whole of northern Europe and the northern parts of North America have had at least one glacial age, during which they were covered with an extensive ice cover as Greenland is at the present time. It was, however, generally believed that Siberia and the whole of northern Asia had had no glacial age, as there were no marks indicating an ice-cover in those countries. During our voyage along the Siberian coast I had an opportunity of visiting the coast at several places, and everywhere I found signs that there had been at one time a glacial covering, an ice mantle over the whole country. We found the coast here pretty much cut up. It did not look as it appears on this map, but looked more like the western coast of Alaska, and more like the coast of Norway.

Outside of the coast there was a belt of islands which we find only along the coasts of lands which have once been covered with an ice cap. This is but an indication that something of the same kind must also once have existed in Siberia. But I found more certain proofs that such had been the case. In one place I saw the rock scratched with glacial striæ and marks, which is a certain evidence that glaciers have once covered that country. In another place I found ground moraines covered with big erratic blocks of various forms, and there is, in my opinion, no explanation of these blocks being there except that they have been carried by glaciers similar to what we know have been in Europe and America.

I have already mentioned some of the evidences on which I founded my theory about the drift of ice across the polar region. I have mentioned that the expedition was accomplished in the way it was planned, and thus the theory was proved to be fairly correct. The expedition has, however, given us a great deal of information which enables us to form a much clearer and better idea of this drift of ice across the polar region than we could have had before. We have had plenty of experience, and have made many observations of how this ice is constantly being drifted from one side of this polar region to the other. What causes this drifting? The drift is for the most part caused by the prevailing winds. The data collected have not been calculated yet, but so far as I can now say the direction of the prevailing winds was pretty nearly the same as the prevailing drifts. Perhaps they do not, however, quite coincide, as I believe there are some other factors which also help to decide the final drift of the ice.

The prevailing winds in this region during the whole year go from this Siberian side (indicating) toward the Atlantic sea, and consequently sweep the whole expanse of ice cover out into the Atlantic sea. That is the main feature of this drift. Of course there are many variations, many periods of drift during the year. At some periods the drift is more rapid. At other times the drift stops, or even goes in the opposite direction. But as a rule the best period for the drift to go in the direction we wanted was the winter and spring, and the worst period, generally, was the late summer and autumn.

I may mention here that the route you see on this map[1] is very much simplified. If we had it marked down as it really was it would not be possible to understand it; it would be so complicated that you would not know one drift from another. During the first autumn we had a drift backward, and were drifted southeast into the shallow sea and toward the New Siberian Islands again. Then the winter came and we were pushed forward until the middle of June, and then came another bad period and we were pushed backward. Then it began to drift onward again until the next year; then there was a stop again during the summer. Then there was a more favorable drift during the winter again until the Fram worked her way out of the ice to the north of Spitzbergen.

You will understand that we are now able to form pretty nearly a complete picture of the motion of this ice in the polar sea. You

[1] An enlarged drawing of a map given in "Farthest North."

see how it is carried across the polar regions from the Siberian side toward the opening between Spitzbergen and Greenland, and also toward the channel between the islands in the North American archipelago. As, however, there is no such gap between these islands as between Spitzbergen and Greenland, the ice there seems to be very much blocked, and is stopped for years and gets very much thicker than on the East Greenland and Spitzbergen side. By snow being heaped upon it year after year it forms striæ similar to what we find in glacial ice; it is what has been called the paleocrystic ice by the English and American explorers.

You understand that our expedition has removed that extended massive and immovable ice-cap, or mantle, which so many explorers thought covered the polar region. Instead we have found a deep sea covered with a comparatively thin layer of ice in constant motion from one side to the other, being one link of the eternal circulation of the ocean.

We had a very good opportunity to study the formation of this ice. I shall mention here only the growth of it by the frost. A good many people, I dare say, believe that the ice in the north goes on growing forever, and that it gets thicker and thicker every year it remains there. That is, to some extent, the case; but it is not quite so simple, and the growth is not so quick as one would generally imagine. In the beginning, as long as the ice is thin, it grows very rapidly. It was measured at certain intervals during the whole expedition. Ice formed in November of the first year, 1893, had in April, 1894, attained a thickness of seven and a half feet. On June 9, it was eight feet three inches thick. That is about the growth of one year. In some parts it was nine feet thick. In the last month of summer and in the autumn it melted a little. At the beginning of the winter, in September, the same floe was about six and a half feet thick. Then the growth began again very slowly, and in May of the next summer, 1895, the same ice had become nine feet ten inches thick. You see it does not increase very much after the first year. The next year another floe was measured. At the beginning of the winter, in November, it was eleven feet thick. At the end of that winter, in May, 1896, it had reached a thickness of thirteen feet six inches. This ice was about three or four years old. The most of the ice that drifts across that region will not grow much thicker directly by freezing, as it is carried across the polar sea, at most, in five years.

By the pressures the ice is, however, piled up to very much greater thicknesses, and ridges and hummocks are formed, the height of which may amount to twenty feet or even more above the water. The highest hummock I ever measured was twenty-three feet high, so far as I remember. I saw a few which I estimated to be about thirty feet high. These hummocks will freeze solid and will last for years. I might mention one which was formed near the Fram in January of our first year, which followed the Fram during the whole time of the drift. This hummock has probably drifted on southward along the East Greenland coast. The ice floes are crushed easily, but these hummocks require much more force to crush them. They will stay together and be the last remnants of the ice to be carried around Cape Farewell and the west coast of Greenland.

The cause of these ice pressures has already been referred to in the accounts of previous expeditions. It is a fact, which has often been observed by various explorers, that the pressures are to some extent caused by the tidal currents. Our observations showed that at the margins, near the outer edge of the polar ice-pack, where there is an open sea to the south, the ice pressure is almost solely caused by the tidal currents. The pressures were there often so regular in their occurrence that we could say beforehand when the ice pressures would occur. We knew that they would come with the spring tide, the heaviest ones a little after new moon, and another period with less heavier pressures about full moon. The pressures would at these periods generally occur twice in twenty-four hours. Then the ship would often be lifted a good many feet out of the water, while in the intervals the openings in the ice would widen out and the ship would be floating in a broad, open channel.

In the interior of the polar ice these tidal currents do not seem to have much influence on the pressures. I could not discover any regularity in them there. The pressures seemed to be caused mostly by the changing winds. It is evident that when the wind suddenly changes, especially to the opposite direction to that from which it has been blowing for some time, immense pressures must arise. The great body of ice is moving on, while in front the ice is moving against it. We had a very severe nip on such an occasion about New Year's day, 1895. I dare say it was the heaviest ice pressure any ship has ever been exposed to, and that was in the middle of winter when the ship was frozen fast in her ice berth.

These ice pressures which form the hummocks that I have spoken of, and which make the ice so much thicker in some places than in others, give room for cracks and open water lanes in which new ice is formed. Thus one must not think of the polar sea as being covered with one even layer of ice. We find floes of all thicknesses from this newly formed ice on the lanes up to the big hummocks which are very deep.

There is one important feature in our discoveries about which I shall say a few words, and that is the temperature of the sea. As is well known, the temperature of the deep sea all over the world is very low. It is not many degrees above the freezing point. In the northern part of the Atlantic ocean the bottom, and in fact the whole sea on the Greenland side, is filled with water two or three degrees below the freezing point. The temperature is about 29.4° Fahrenheit through nearly the entire depth from the surface down to the bottom. Of course as far as the Gulf stream runs north the surface is very much warmer. As the polar sea sends southward such a cold current, filling the whole depth of the North Atlantic, you would naturally expect the whole polar sea to be filled with such cold water. But such is not the case. We found that from 100 fathoms under the surface of the polar sea down to the bottom the water is warmer than we find it in the depth of the North Atlantic ocean. I will give you a few of the observed temperatures. The surface of the polar sea is covered with a layer of water of comparatively low salinity, and is very cold. But when you penetrate down through this layer you find that the temperature begins to rise. At the surface you find the temperature —1.5° Centigrade, which means 29.3° Fahrenheit. But at a depth of 110 fathoms you suddenly come on warm water, the temperature of which would be as much as 32.9° or even 33.4° Fahrenheit, which you see is very much warmer than you would expect or than you find in the deep sea in the North Atlantic ocean.

At a greater depth the temperature varied somewhat, but remained about the same to a depth of 220 to 270 fathoms, after which it sank slowly toward the depths, though without sinking to the cold temperature of surface water. Near the bottom it again rose quite slowly. These conditions were fairly uniform in that part of the sea over which we traveled and where investigations were made.

It may seem rather striking that the sea should be so warm in the depths and so cold on the surface. The reason is natural. I may say first that the cold surface layer of water was fresher than the lower warm layers. The deeper water had a high salinity very much like the Atlantic water. That is the reason why this warm water is heavier than the cold water and keeps below. All this salt and comparatively warm water runs into the polar sea from the Atlantic ocean, filling the whole depth of the polar basin, while its surface water to some extent is mixed up with the fresh water running in from the American and Siberian rivers.

The Atlantic water is slowly cooled down and is gradually, to some extent, mixed with the fresher water of the surface and is then again carried out into the Atlantic ocean as water with less salinity than the Atlantic water and much colder; and on that account is heavier and sinks and fills the bottom of the sea. What is the result of these conditions? The result is that the fresh water floating on the top of the salt warm water protects the ice to some extent from the influence of the heat which is carried into the polar sea by the Atlantic water. It allows that ice to grow slowly year after year. If this fresh water had not existed the Atlantic water would come to the surface in the polar sea, and this covering of ice would consequently be very much thinner.

If we look backward through the ages and ask what the result would have been if the geographical distribution of the land and water were a little different from what it is to-day, what result would we expect? What would the result be if we were to shut up the whole polar basin, not allowing this warm water to flow into it and not allowing the ice and the cold water to float out of this polar sea? If we had a bridge of land passing from Greenland to Iceland and across to the Faroe and Shetland Islands, uniting Scotland and England with Greenland, and consequently closing up the whole entrance to the polar sea, what would be the result?

The result would be that no warm water would be carried from the south to the polar region; the ice would be allowed to block up there year after year and would not be allowed to drift across and out, and by and by the whole polar sea would necessarily be covered with a very much thicker layer of ice and snow than at present. This layer would at last have no more motion and the thickness of the ice would allow the temperature to fall during the winter on account of the radiation of heat from the surface. This would produce a cooling down of the polar region to a much greater extent than exists to-day.

Consequently we would have in the north a colder climate, and we would at the same time have a warmer climate in the south, because the ocean would not be cooled down by the northern ice, and it would be prevented from giving off a good deal of its heat to the polar region. That might to some extent explain a colder climate in the north and a warmer climate in the south, but I do not think it would be sufficient to explain the glacial periods. It gives us, however, some idea, or some factor that would explain the changes of climate on the surface of the globe.

You might ask what would be the result if we could open out the entrance to the polar sea and let more warm water flow into it. If, for instance, the Bering's Strait could be made much wider and deeper than at present, so that the warm Japanese current, the Kurosiwo, could run into the polar sea, its temperature would then, of course, be very much higher than at present. It would still be covered by a layer of fresher water from the rivers flowing out of Siberia and America, but the thickness of the ice would be less than at present. If we, however, could let the rivers of Siberia flow in some other direction, not going into the polar sea, but somewhere else, so that the polar sea would not be covered by such a layer of fresh and cold water, what would be the result? The warmer water would then come up to the surface, the ice would necessarily be thinner, we would get much more open sea in the north, and to some extent the climate would be milder. At the same time much more cold water would run out of the polar sea into the Pacific and Atlantic oceans, and would cool down the temperatures in those latitudes.

I do not think this explanation is sufficient to account for the much warmer climate in the north when we, for example, had a subtropical climate in Greenland and Spitzbergen. At the same time it may give you some idea of what such changes in the distribution of the land and water would result in.

I will not go further into these very difficult questions. I just mention this to show you what glimpses polar exploration might give us into the conditions existing during other ages of the earth. This is only one side of the many results which polar explorers have brought back from the polar regions. They have to a great extent enlarged the knowledge of humanity. They have made it possible for us to form ideas of the past history of the globe which we would not have been able to form had not man gone out to explore these regions.

I hope to see new expeditions start soon again for these regions, and I trust that especially this great nation will take an important part in them. We know from what you have accomplished in the past that you will be able to achieve great results to the benefit of the nation and to the benefit of humanity.

COMMODORE GEORGE W. MELVILLE:

It is with a great deal of diffidence that I arise to speak at all in discussion of so clever a discourse as that of Dr. Nansen, much less to criticise it, for my experience in three different Arctic voyages, in different Arctic seas, has taught me that only those who are in the same field at about the same period can have the requisite information to undertake a critical discussion. Moreover, Dr. Nansen's experience with respect to ice conditions, its formation, drift and other phenomena, so fully agrees with my own in the Jeannette, that there is no room for argument.

However, my sojourn of twenty-two months in a drifting pack of no mean proportions, extending from the Pole south to 70°, emboldens me to speak of some experiences, second only to those of Dr. Nansen and of Weyprecht and Payer of the Tegethoff expedition of 1871 to 1874.

The Jeannette, Capt. De Long, U. S. N., was boldly pushed into the ice in latitude 71° 35′ N., 175° W., as we then believed the theory of Dr. Petermann, the celebrated German geographer, that Wrangel Island might be of continental proportions, extending to the northward and eastward toward the Pole, and possibly extending so far to the eastward as to overlap the northern part of Greenland. It was thought to be what some explorers had supposed to be land seen to the northward of the Spitzbergen, and extending as far to the eastward as the archipelago formed by the Spitzbergen on the west and Franz-Josef Land on the east.

It took us but a few days to prove that Wrangel Land was only an insignificant island, as we drifted across its northern face, at times in as little as thirteen fathoms of water; and at times as close as fifteen or twenty miles to its northern shores.

It is needless to state that drifting in a heaving pack in so shallow a sea was most hazardous, the underrunning and overrunning of the floes causing them to telescope and rise to heights at times approaching 100 feet.

After our ship was solidly frozen in, she was never again released until she was finally crushed on June 12, 1881, after we had drifted twenty-two months in a zigzag course, many times lapping and crossing and recrossing our track. The resultant of our drift was north, 45° west true, distance 1300 miles, when our floe broke up, and the ship was crushed, in latitude 77° 15′ N., 155° E., leaving us 500 miles in a bee line from the nearest point of succor, the mouth of the Lena river, Siberia. We were left on the ice, thirty-three officers and men, with seven on the sick list, and with the disheartening prospect of hauling our baggage an indefinite distance to clear water. It consisted of eight pieces, giving each man fit for duty a load of 290 pounds to haul.

Just here, let me call attention to the very important fact that the Jeannette expedition is the first on record where such a long imprisonment in the Arctic pack was not accompanied by scurvy. The Lady Franklin Bay expedition, under the command of Lieut. (now General) A. W. Greeley, U. S. A., was the second up to the date of our wreck which had escaped the dread scourge. Our good fortune, so different from the experience of previous expeditions, can be clearly traced to good food, distilled water, good sanitary conditions, a light, though healthy diet, and abundant outdoor exercise, not of a laborious or wearying nature, every day in the year.

You will, I am sure, pardon me for introducing a few facts of the drift of the Jeannette, as leading up to the drift of the Fram, for Dr. Nansen put his ship into the ice to commence his drift about where the Jeannette let go, though a little farther to the westward. In other words, the Fram finished the drift that was commenced and prosecuted by the Jeannette involuntarily, for our intent was to go to the northward and eastward. But, after being beset in the pack, and drifting across the north face of Wrangel Land, we were pretty sure that there was no possible retracing of our course, unless, by a swirl or turn of the floe, we might be cast out on the coast of Siberia, as the whaleship Mount Wollaston and others had been, which were visited by the native Tschuckchees and found abandoned.

As the cartographer of our expedition, I was directed to make a circumpolar chart showing every known current that had been laid down by Arctic explorers, from the time of Barents and Willoughby to date. We were fortunate in having a very extensive Arctic library on board, and, as the discussion of Arctic literature and the formulation of theories and conjectures were among our pleasantest ways of passing time, you can well imagine that, with eight intelligent readers in our cabin mess, it was not long before I had a chart with hundreds of arrows denoting currents as laid down by voyagers for more than 300 years. It was remarkable how plainly they pointed to the fact that, if our ship should hold together and our provisions last, we should drift out either by way of Franz-Josef Land and Nova Zembla, or, taking the northern cant across the north face of Franz-Josef Land, between the Spitzbergen and east coast of Greenland. That was as well understood and believed by the officers of our ship as it is to-day proved by Dr. Nansen.

In addition to what we learned from our drift chart, we also knew that drift wood covered the east side of the Spitzbergen, Franz-Joseph Land, and even the northeast coast of Nova Zembla, where grand old Barents wintered, and it was certain that this was brought by the great Siberian rivers discharging into the Arctic ocean. These facts had all been established before our time, but none of us then supposed for a moment, nor do I now believe, that this débris would drift across the North Pole. In fact, I have not believed hitherto that it ever drifted beyond 85°, but Dr. Nansen and the drift of the Fram have demonstrated that it has drifted north of 86°. So I must concede that latitude, at least, as possible for drift wood to reach.

There were, however, two great "ifs" in the way of our accomplishing this long drift: Could our ship hold together; would our provisions hold out? We had pumped our ship night and day for twenty-two months, at first by hand and steam power, afterward by a wind-mill that was extemporized on board ship, supplemented by hand power, or steam, as the emergency arose. The merry "chug" of the pump night and day, for twenty-two months, never ceased. Our game in the far north had become scarce, and we had not added much to our larder beyond a few seals, walrus and bears we had taken in the early part of our drift, in the spring of 1880.

After many consultations about the situation by the officers of the ship, and a close account of the provision list, it became manifest that our provisions would be exhausted before January, 1882. So, the question was whether we should abandon our ship in the spring of 1881, or the fall of the same year. As seamen, loyal to our ship and duty, we decided to remain by the ship as long as possible, though sober judgment taught us that the proper time to abandon the ship was in the spring, which would give us mild weather and summer game to assist us on our retreat. At that time, we were nearly due north of the New Siberian Islands, which seemed like stepping stones toward the Lena river and the coast of Siberia.

The problem was solved for us by the breaking up of the floe, which, in time, crushed our ship; and, amidst the crashing and grinding of the poor old ribs of our good ship, we were cast out, Cæsar-like, from the bowels of our good mother Jeannette, who had sheltered us and kept us warm all these months.

At this very time we were making our most rapid drift to the northward and westward, and it was impressed upon us in a most startling and disheartening way. The Jeannette was crushed and sank in latitude 77° 15′ N., longitude 155° E.; after marching southward twenty-one days, we found ourselves in latitude 77° 36′ N., longitude 153° E., or actually *twenty-eight miles northwest of where we had started* and at the most northerly point of our voyage. This rapid drift is the key to the situation pointed out to our good friend, Dr. Nansen, who had the sagacity to seize the idea and to originate the theory that has led to his great success.

As I have said, our retreat lay directly south, about five hundred miles in a straight line. At the start we had sixty days' provisions, allowing one and a half pounds per man per day. Most of our dogs had died during the first winter, and of the remainder we shot all but eleven good ones, which, however, rendered very little service, eating nearly as much as a man and doing about one-tenth as much work, so that we finally shot them also.

Thus we journeyed, dragging our boats and provisions on sledges over the broken floe, and finally taking to the boats to cross the open sea to the Siberian coast. It was the stormy fall season of gales, ice and snow. Our small open boats were often in danger of foundering, and in the fiercest of the gales Lieut. Chipp's boat was swamped, drowning him and his seven men.

The other two boats, those of Captain De Long and myself, succeeded in reaching land, although one hundred and fifty miles apart, thus ending our long retreat of one hundred and ten days. De Long and all but two of his men perished of cold and starvation. My crew of eleven all told were more fortunate, all being saved, although one died of smallpox in Siberia on the way home. The total loss was thus sixty-six per cent. of the personnel of the expedition, and of the original survivors there are only six now alive.

Now, as regards our drift. It was quite evident that, for the first eighteen months at least, our drift was caused by the fierce southeasterly gales that drove the pack up into the northwest. We can conceive the effect of the innumerable hummocks of ice, like millions of sails set to catch the breeze. After the subsidence of each gale, we took a rapid setback drift to the southeast. In fact, in the spring of 1880, after our first winter in the pack, we were driven back in sight of Wrangel Land to about the place where we were first beset, which accords with Dr. Nansen's experience.

Dr. Nansen found a deep sea to the northward and westward of the line of our drift, which is the exact opposite of our experience in the part of the ocean we traversed. Although soundings were taken every day at noon, they never but once showed more than from thirteen to thirty-six fathoms. Even this greatest depth was only eighty fathoms, which occurred at the most northern point of our drift during the winter of 1880.

I had a theory of an ice cap at the Pole (which, by the way, our good friend, Dr. Nansen, has very materially shaken) extending down to about 85°, against which I believed the drifting pack impinged. Between this supposed ice cap and the drifting pack, in the shallow sea in which we were drifting, I conceived a canal of comparatively deep water, which my messmates in derision called "Melville's Canal." It is needless to say, however, that I was pleased, as were also my messmates, to find that we were on the edge of "Melville's Canal" when we got a cast of the lead in eighty fathoms of water, and they conceded that my theory of a deep canal might be correct, so that, in our theories at least, "Melville's Canal" had a recognized standing.

Unfortunately, after the southeasterly gales had ceased to blow, we were rapidly drifted back again by the receding ice, and never again got far enough north to find the deep water where currents alone can run. It is impossible for any geographer to conceive of a natural sea current in a shallow sea of thirty fathoms. Local currents, it is true, may be caused by wind or tide, if there is any; or by the outflow of great rivers, but a natural current of inlet and outlet, caused by the heated or chilled waters, such as the mighty Gulf Stream, or the Kuro Siwo of Japan, can only run and be maintained in water whose depth is measured in hundreds of fathoms. Such seas we did not find. Hence, my theory of wind currents in a shallow sea. Another fact of our drift is that our floe was continually swinging around, not always in the same direction, as our ship's head pointed to every point of the compass, though frozen solidly into the moving pack, demonstrating the fact that the great floe itself was in a "swirl." Dr. Nansen was more fortunate in early striking "Melville's Canal," where the water was deep enough to permit ocean currents to run.

Now, as regards the shallow sea over which the Jeannette drifted: Is this shallow sea caused entirely by the silt of the great northern rivers, or is it partly caused by the erosion of the land? The islands that extend all the way from the Lena Delta to "Bennette," "Jeannette" and "Henrietta," like so many stepping stones from the mainland toward the Pole, were, in my belief, at no very distant period, part of the mainland of Siberia. They are daily being eroded by the drifting ice pack; and, in time, nothing but the bare rocks will remain of these islands.

During our short stay on these islands, while on our march to the south, and while we were in the Lena Delta, the land was not making, but the daily evidence of the constant washing away by sea and ice floe, or melting snow, and occasional rain, showed that the islands were being denuded and eroded away.

I saw, on the banks of the Lena Delta, immense trunks of trees, with roots attached, that had apparently fallen *in situ*. Forty feet above the bed of the river, these lands were gradually washing away. These lands and the islands of the Arctic sea still show the remains of the mammoth which, without doubt, was a native of the mainland, and of the islands when they were part of the mainland. We found remains—tusks and teeth of the mammoth—as far north as Bennett Island, and, I doubt not, had time sufficed, similar remains would have been found on the other islands visited by the Jeannette.

I have thus digressed, gentlemen, from the main question of Dr. Nansen's drift, in order to justify the theory of a shallow sea more than 1500 miles in extent, east and west, though perhaps local in its northerly extension.

And now that Dr. Nansen has made the most magnificent drift on record, attained the highest latitude known to man, and made the most fortunate and masterly retreat, let us say, "Well done, Nansen!" and let us plan the next possible drift from the east toward the west to make a high northern latitude, reaching, if possible, within marching distance of the Pole.

If Dr. Nansen is correct in his conjecture that we have deep water and broken ice, with open "polynias" all the way to the Pole, and, if my theory of a solid ice cap at the Pole (like an inverted saucer) is wrong, let us theorize a little further, and seek the best place to put a ship in the pack for such a drift as is contemplated. Let us see where our ship, if she holds together (which is doubtful), or if not crushed (possibly being buried in the overlapping and underrunning floes), let us conjecture, I say, the best place to put the ship in the pack for such a drift.

Dr. Nansen took several months to proceed from Norway, along the coast of Siberia, toward the river Alaneck, before he pushed north to take up the drift about where the Jeannette let go and sank in thirty-four fathoms of water, thus losing valuable time after leaving any source of supplies.

We must get north as rapidly as possible after leaving our last depot of provisions, so that if Dr. Nansen's theory of the Arctic ocean currents and of the ice conditions toward the Pole be correct, I believe that the proper place to put a ship in the ice will be through Bering strait. We should keep along the east edge of the pack in about longitude 165° W., attaining the highest possible latitude, and westerly longitude, culminating together. Then we should push the ship into the pack as far as possible to the northward and westward, and await the fulfillment of the prophecy of one of the jolly whalemen I met at San Francisco. He said: "Melville, push her into the ice at about the point I have mentioned, and you will either go to the Pole or to hell, and I believe the chances are about even." I can't agree with my whale-fisher friend about the hell part of the business, for true philosophers have a right to disagree about that. I do believe, however, from the information we have gained from the drift of the Jeannette and of the Fram, that vessels of any kind, such as casks or driftwood, will come out by way of the Spitzbergen—though not necessarily across the Pole. The only reason for sending in ships and men is that there may be observers to make a daily record of events, and of phenomena, such as latitude, longitude, soundings, daily drift, dredging the ocean's bottom if possible; in fact, recording all the phenomena proper on such an expedition. But for this, I say, a hundred oaken casks, properly numbered, made after the manner of a beer keg of twenty gallons capacity, properly hooped, and the ends extended out to complete a parabolic spindle, would demonstrate the drift. At the end of four or five years, we might begin to look for the beer kegs between the Spitzbergen and Greenland. And now, as regards the work of our honored guest this afternoon:

His is the honor to have reached the "Farthest North," the *Ultima Thule*, that has defied the best blood and brains for three centuries. He it was who conceived the grand thought of making that most perilous drift, though he knew not how long it might last, nor whether his good ship and ship's company would ever drift out of the terrible unknown sea of ice and snow. His was the honor—after waiting months and years for the slow drift, and becoming impatient of the gods of ice and snow—to break away from the good ship in order to add a few more miles to his northern journey; and, taking his life in his hands, with but one solitary human companion, to make the long and dreary march to Franz-Josef Land. And to what purpose? That we, the eager, driving, working world, might have that knowledge which is power, wealth and happiness.

And let me ask my hearers this afternoon, What better school of heroic endeavor for our lusty youth than the Arctic ocean? There, amidst the silence of the eternal ice and snow, man can commune with the God of Nature in the hushed stillness that brings awe, but not fear, to the soul of the intrepid explorer, and there he receives the inspiration that spurs him onward in his search for the great unknown!

This, gentlemen, is Dr. Nansen, the guest whom we delight to honor, who among Arctic explorers is "the noblest Roman of them all."

PROF. ANGELO HEILPRIN:

Mr. President, Ladies and Gentlemen:—I was asked to speak this afternoon, and inasmuch as my resources in Arctic exploration are extremely limited, it is doubtless expected of me to say something on the scientific aspect of the subject, something of what remains to be done and something that has been done.

The question of the existing and past relations of the land and water areas in the far north is an exceedingly interesting one to the geologist. I have given it a considerable amount of attention, but have arrived at no absolute conclusion to which I should like to commit myself at present. For some months past I have been engaged in the preparation of a geological map of Arctica, more particularly with reference to the results obtained by recent explorations. It is hardly necessary for me to state with what expectancy we are looking forward to the publication of the minute geological details which have been obtained by Dr. Nansen.

As geologists, we have gone sufficiently far to be able to state certain facts. Perhaps the most important of these is the very strong likelihood that, where we find to-day the deep ocean discovered by Dr. Nansen in place of the shallow sea that was thought to exist in the far north, its place was at a period not so very remote covered by land, and instead of a polar sea we had once a polar continent. Dr. Nansen has given to us very conclusive evidence as to the condition of Siberia at the not very remote period when in the general temperate regions of the north we had glaciers running down different mountain slopes, extending to the lower valleys, cutting out the fjords and valleys in the Scandinavian peninsula, like those which we to-day find in Greenland. Since that time, not more perhaps than fifty, seventy, or a hundred thousand years ago, the condition of the country has entirely changed, and changed to such an extent as to have deceived the geologists into the belief that there never was a glacial period touching the Siberian frontier. The discovery made by Dr. Nansen, and still earlier that of the Russian traveler and geologist, Baron Von Toll, who seemingly found a fragment of the old glacial ice existing to-day, and in addition the remains of animals, such as the tiger and rhinoceros, in the deposits of the New Siberian Islands, speak conclusively of great changes of climate and of oceanic configuration.

One great pleasure I experienced on the comparatively small venture I made in the north was in searching in the deposits of Atanekerdluk, Greenland, in approximately latitude 70° N., for the remains of old foresters, the history of a forest of warm temperate aspect, with trunks and leaves indicating a growth largely identical with or similar to that found to-day in Japan, and in localities where the redwood grows in the United States, and where we have poplars, elms, maples and oaks. The dimensions of the trees measured perhaps a hundred feet or more in height; to-day the full height of vegetation of the same region is measured by six, eight and ten inches.

The evidence appears conclusive to my mind that we had the whole northern part of this tract of the world covered by a land-mass uniting Greenland not only with Spitzbergen but also with Franz-Josef Land and northern Siberia. Dr. Nansen, I believe, gives the best evidence for assuming that Franz-Josef Land is merely a fragment of what was once united with Spitzbergen; and if we had this connection it is practically certain that its relations were continental. What the result of such continental association may have been geologists have not yet been able to determine, but it will be one of the objects for explorers to make clear to us in the future.

I think it was the Austrian geologist, Prof. Eduard Suess, who first clearly pointed out the enormous changes that are taking place on the face of the earth through downward breakages, and that even the Atlantic ocean is but a depression of a comparatively recent date (of course from a geological point of view). It may not have been in existence more than 200,000 years, possibly for one or two million years. In the Arctic regions we have evidence that what is now water was once land, not very many thousands of years ago. A second proposition brought out by Dr. Nansen in reference to the relation that Bering Strait bears to the geology and geography of the region of land to the north, points to its having been opened in comparatively recent times, and that breakages are taking place to-day we have the best of evidence. The eastern remnants of the old Asiatic connection, which at one time extended to the outlying islands, are monuments of this form of destruction.

This largely indicates the direction in which to look for the solution of the problems that the results which Dr. Nansen has given to us have raised. Scientific expeditions have been fitted out from New York to explore that very Asiatic tract for further evidences of these breakages. We know, too, that the foremost explorer of this city—I refer to Lieut. Peary—is preparing for an expedition to penetrate into the solitudes of the northernmost part of Greenland and of the regions beyond; and we have learned from recent reports that Capt. Sverdrup is at the present moment preparing for another exploration of the far north to supplement the brilliant results of Nansen.

It is not my intention to detain you longer, and I will only express the hope that expeditions of this kind may continue to be sent out until the entire northern tract is known to us in exactly the way that much of it has been made known by Dr. Nansen.

Stated Meeting, November 5, 1897.

Vice-President Pepper in the Chair.

Present, 28 members.

Mr. Theodore N. Ely and Mr. Richard H. Sanders, newly elected members, were presented to the Chair, and took their seats in the Society.

Acknowledgments of election to membership were read from Mr. George Wharton Pepper, Commodore Melville, Mr. Gregory B. Keen, Mr. George Vaux, Jr., Hon. Wayne MacVeagh, Mr. John C. Smock, Hon. Grover Cleveland, Prof. William Libbey, Capt. Alfred T. Mahan, Prof. Woodrow Wilson, Dr. George A. Piersol, Prof. Lightner Witmer, Prof. James M. Baldwin, Mr. Richard H. Sanders, Mr. James S. deBenneville, Prof. Henry M. Howe, Mr. James B. Leonard, Prof. Edward H. Williams, Prof. H. Morse Stephens, Mr. William Tatham, Mr. Clarence B. Moore, Mr. Charles R. Hildeburn.

Donations to the Library and Cabinet were reported, and thanks were ordered for them.

The decease of the following members was announced:

Prof. James Ellis Humphrey, of the Johns Hopkins University, on August 17, 1897, at Jamaica, W. I.

Justin Winsor, LL.D., Librarian of Harvard College and President of the American Library Association, at Cambridge, on October 26, 1897, æt. 86.

John Sartain, at Philadelphia, on October 25, 1897, æt. 89.

The Society resolved itself into the Committee of the Whole, and proceeded to the consideration of the proposed amendments to the Laws.

The Society adjourned until Wednesday evening, November 10, at 8 o'clock.

Adjourned Stated Meeting of November 5, 1897,
November 10, 1897.

Vice-President Pepper in the Chair.

Present, 20 members.

The Society met pursuant to adjournment, and resolved itself into the Committee of the Whole, with Mr. Garrett in the Chair. The Committee resumed the consideration of the proposed amendments to the Laws.

The Committee of the Whole rose and reported, and on motion the meeting adjourned to Wednesday evening, November 17, at 8 o'clock.

Adjourned Stated Meeting of November 5, 1897,
November 17, 1897.

Mr. Garrett in the Chair.

Present, 14 members.

The Society resolved itself into the Committee of the Whole, and resumed the consideration of the proposed amendments to the Laws.

The Committee of the Whole rose and reported, and the Society was adjourned by the presiding member.

Stated Meeting, November 19, 1897.

Mr. Richard Wood in the Chair.

Present, 10 members.

Letters of acknowledgment of election to membership were read from Dr. E. R. Squibb, Sig. Rodolfo Lanciani and Mr. Charles D. Walcott.

Donations to the Library were reported and thanks were ordered for them.

The decease of the following members was announced :

Mr. William Woodnut Griscom, of Philadelphia, on September 24, 1897, æt. 46.

Dr. Harrison Allen, at Philadelphia, on November 14, 1897, æt. 56.

Mr. R. H. Mathews presented a paper on "Rock Carvings and Paintings of the Australian Aborigines."

The Society resolved itself into the Committee of the Whole, and continued the consideration of the proposed amendments to the Laws.

The Committee rose and reported. The Society resumed its session, Vice-President Pepper in the Chair.

The Finance Committee reported upon the legacy of Henry Phillips, Jr., deceased.

The meeting was adjourned by the presiding officer.

ROCK CARVINGS AND PAINTINGS OF THE AUSTRALIAN ABORIGINES.

(Plate X.)

BY R. H. MATHEWS, L.S.

(*Read November 19, 1897.*)

INTRODUCTORY.

The wide distribution throughout Australia of these native drawings would lead us to expect that the figures of animals and various objects carved upon large rocks—and the groups of hands, varying in number and in relative position, as well as weapons and other tribal devices painted on the walls of caves—had some symbolical meaning in connection with the myths and superstitions of the natives, or were commemorative of events and scenes in the history and life of the tribes. Most of the figures of animals were probably intended to represent the totems of the different families; but it seems reasonable to suppose that some of the smaller drawings and nondescript devices are the result of idle caprice. The production of some of the larger groups—both of carvings and paintings—has been a work of immense labor, and it is unlikely that the natives would have taken so much trouble for mere amusement.

Aboriginal drawings are almost everywhere of the same character, with but little variation either in the subjects treated or in the style of workmanship. They consist chiefly of stenciled and impressed hands, outline drawings of human forms, animals and a few nondescript devices. In many of the caves we find groups of lines varying in length from about four inches to two feet. Sometimes the series consists of two or three lines; in other cases there are as many as about a dozen. They are generally drawn vertically or only slightly inclined, but are occasionally met with in a nearly horizontal position. The native artists had no idea of perspective, and their figures are not copied from nature, but are apparently drawn according to some conventional pattern which has probably been handed down from a remote period. The stenciled drawings cannot be called copying from nature, and may, therefore, be included in the conventional type.

Owing to our limited acquaintance with the subject, it would obviously be premature at present to advance any far-reaching theory as to the signification of these drawings. What we should endeavor to accomplish is the collection of all the facts now obtainable respecting these works of native art, by careful observation and inquiry in all parts of Australia. This would, I feel convinced, yield results of more than ordinary interest. The information thus gathered should be systematically compared and classified, from which it may be possible for us to arrive at some definite conclusion in reference to the purpose of these drawings, and perhaps furnish an important link in regard to the prehistoric colonization of this continent. This work should be undertaken without delay, because the farther we get away in point of time from the period of production of these pictures, the more difficult will it obviously become for us to obtain satisfactory explanations as to their meaning and origin. There are many difficult points which require much closer attention than they have yet received.

Writing under the date of February, 1788, Capt. Watkin Tench mentions some carvings seen by him upon rocks in the vicinity of Sydney;[1] and in January, 1803, Capt. M. Flinders discovered some

[1] *A Narrative of the Expedition to Botany Bay* (1789), p. 79.

rock paintings on Chasm Island, in the Gulf of Carpentaria.[1] These are the earliest authentic records of the discovery of carvings and paintings respectively in any part of the Australian continent, so far as I am aware. Since that period rock paintings have been found in several places in West Australia, South Australia, Victoria, Queensland and New South Wales. The rock carvings have also been observed in a few localities, long distances apart, in all the colonies mentioned with the exception of Victoria. The fact of these carvings not being reported in Victoria may probably be attributed to their having escaped the notice of investigators rather than to their non-existence.

Among the Darkinung tribe of aborigines, who occupied the country from the Hunter river to the Hawkesbury, I had the good fortune to meet a few natives who told me that when they were boys they had seen both painting and carving on rocks done by their countrymen, between the years 1843 and 1855, and it is probable that the practice was continued for some years later. From the last-mentioned date to the present the blacks have disappeared very rapidly by death, and the few survivors have lived chiefly amongst their white supplanters, abandoning most of their former customs.

To those who may be desirous of taking part in investigations respecting this subject a few practical directions relating to taking the necessary notes and the subsequent preparation of the plates for publication may be found of some assistance. The investigator should provide himself with a suitable note-book, a pencil, a tape measure of thirty-three or sixty-six feet in length and an ordinary pocket compass.

On reaching a cave containing paintings a careful sketch of all the figures in the relative order in which they appear upon its walls should first be made. Then note down the dimensions of every figure in this sketch, and at the same time fix by measurements their relative position to each other. If the paintings consist of different colors these should be carefully noted in the sketch. The dimensions of the cave should be measured, and the direction which it faces should be taken with the pocket compass; the bearing and approximate distance from some conspicuous or well-known point should also be stated, as this information will greatly facilitate its identification by others.

In making notes of carvings found on the surfaces of rocks a

[1] *A Voyage to Terra Australis*, Vol. ii, pp. 188–189.

similar course may be adopted, sketching and measuring each figure. The width and depth of the grooves along the outlines should be ascertained, and the direction which the rock slopes stated. In any case of either paintings or carvings where the investigator has not time or is unable for any other reason to copy the drawings, he should describe them as fully as possible, and state their geographical position as nearly as he can, for the purpose of enabling others to find them at any future time.

In reproducing cave paintings from the notes taken in the field they should first be outlined in pencil in their relative positions from the sketches and measurements given in the field book, and afterwards drawn in the colors in which they appear on the rock. The carvings will be reproduced in the same manner and then drawn in with Indian ink. Plates for publication should be drawn the size, or some multiple of the size, of a page of the journal in which they are to appear. It is generally found more convenient, especially if the objects are small or numerous, to draw the plate on a larger scale than that required, because it can afterwards be reduced by photography or otherwise to the proper size for publication.

In describing the rock pictures of the Australian aborigines and explaining how they were executed by the native artists, it will be desirable to treat the subject under two divisions, one being headed "Carvings" and the other "Paintings." In the former the outlines of the figures were in some cases cut and in others ground into the surface of the rock with sharp-pointed pieces of stone; in the latter the pictures were painted on the rock in the required colors; different methods being employed in doing the work.

Rock Carvings.

Rock carvings are found in districts abounding in large masses of rock, chiefly of the Hawkesbury series, but sometimes granitic and metamorphic rocks are used, where the softer sandstones are not available. Occasionally the rock surface containing the carvings is almost level with the surrounding land, and in other cases the drawings have been executed on the tops or sides of rocky masses several feet high. Some of the smallest of the rock surfaces on which these delineations appear do not exceed ten feet square, but they are generally much larger, and in a few places the table of rock, intersected here and there by fissures, was scarcely less than two acres in extent, the carvings being numerous and widely scattered over it. These drawings are generally found on the tops of horizontal rocks, but are sometimes met with on the smooth walls of rocks occupying various slopes between the horizontal and the perpendicular position.

Denuded rocks are more general on the tops and sides of hills than elsewhere, owing to the soil and disintegrated matter being carried away by the weather to lower levels, hence we find these carvings more numerous in such situations than in the valleys, where masses of rock are less plentiful. It is obvious, however, that the natives, with their primitive tools, would be guided more by the suitability of the rock for their purpose than by its location; but where circumstances permitted, preference seems to have been given to rocks occupying prominent positions or which were situated in mountain passes along which the natives traveled from one part of their hunting grounds to another. Fine-grained sandstones of a durable character, with tolerably smooth surfaces and in dry situations, appear to have been chosen.

In nearly all carved figures, owing to age or weathering, the grooves along their outlines have assumed the same color as the original undisturbed surface of the rock. Some of them can be seen without difficulty, but numbers of them are so much defaced by long exposure to the weather that it requires some practice to be able to distinguish them, and they would be passed by unobserved by any person unaccustomed to them. They are more easily seen on sunny than on cloudy days on account of the light falling on all parts of the figure when viewed from different standpoints. The best time to observe those which are very faint is either on a dewy morning shortly after sunrise, or any time after a shower of rain; the dew or the rain, as the case may be, collects in greater quantities in the grooves than elsewhere and indicates their position.

Some of the carvings are so indistinct that it is necessary to make a chalk mark along the grooves before a complete idea of the outline of the figure can be obtained. Most of them exhibit tolerably strong likenesses of the objects they are intended to represent, but some grotesque drawings occasionally met with were probably intended for legendary monsters, or creatures of the native artist's imagination.[1]

[1] For examples of these mythologic and strange drawings, see my papers in the following publications: *Proc. Roy. Soc. Victoria*, vii, N. S., Pl. ix, Fig. 10; *Proc. Roy. Geog. Soc. Aust.*, Qld. Brch., x, Pl. ii, Fig. 15; *Am. Anthrop.*, Wash., viii, Pl. ii, Fig. 30; *Journ. Anthrop. Inst.*, Lond., xxv, Pl. xvi, Fig. 6.

In the production of rock carvings three methods were employed by the native artists. 1. That most generally adopted was to cut the outline of the required figure on the rock. It is probable that the object to be delineated was first designed by making a mark with a piece of colored stone or hard pebble along the lines to be cut out. A number of holes were then made close together along this outline, and these were afterwards connected by cutting out the intervening spaces, making a continuous groove of the required width and depth. From the appearance of the punctured indentations made along the lines thus cut out, I am led to assume that the natives had a hard stone or pebble chipped or ground to a point and used as a chisel. Such a chisel could have been used either by holding it in the hand or otherwise and hitting it with another stone, or by fastening a handle to it and chopping with it in the same way that a tomahawk is used. As soon as the outline was chiseled out to the required depth, it is not unlikely that a stone tomahawk, in addition to the chisel, was used in completing the work, because the sides of the grooves were cut more evenly than would have been possible with such an instrument as that with which the holes were punctured. From the smoothness of the edges of the grooves in a few of the best executed figures I am inclined to think it probable that after the chiseling and chopping out was finished the edges were ground down by rubbing a stone along them, to give them an even and regular appearance.

2. In other instances the whole surface of the rock within the outline of the figure was cut away to the same depth as the exterior groove, as in the cases mentioned by Capt. Wickham in his description of the carvings on Depuch Island, on the coast of West Australia, published in the *Journal of the Royal Geographical Society*, London, Vol. xii, pp. 79–83.

3. Another method was to trace on the rock all the lines of the object to be drawn, and then to form a groove by repeated rubbing with a hard stone or pebble along the outlines which had been so designed until the entire figure was completed. Carvings executed upon rocks in this way have been observed in West Australia and in some of the other Australian colonies.

In a previous communication to this Society[1] I furnished a plate containing sixty-one figures of men, women and children, kangaroos, emus, fish, wombats, snakes, native weapons, etc., together with

[1] Proc. Amer. Philos. Soc., Vol. xxxvi, pp. 195, Pl. iv, Figs. 1–61.

some land and marine monsters the types of which do not exist in nature, so that it will not be necessary on this occasion to add any further examples of aboriginal carvings. The present article, taken in conjunction with my former paper, will be found to place the subject of Australian rock pictures in a tolerably complete form before scientific men who may be engaged upon similar investigations in America.

Rock Paintings.

Cave paintings are necessarily restricted to those parts of Australia in which suitable rocks for the purpose are obtainable. They are sometimes met with in weather-worn cavities at the bases of separate boulders, but much more generally in rocky escarpments, of more or less continuity, on the sides of hills or watercourses. These cavities or shelters owe their origin to the natural wasting away of a softer stratum of the rock, leaving a harder layer overhanging, which forms the roof of the cave. In most cases they get narrower and lower as they go back into the rock; but some are small at the entrance and become higher and larger as they recede, having a somewhat dome-shaped interior. Some of them are of great extent, being more than one hundred feet in length, upwards of twenty feet high and extending back into the rock about twenty-five feet; while some are merely shallow crescent-shaped hollows of small dimensions weathered out of the face of a boulder or escarpment.

Many of the larger shelters have been used by the natives as camping places for considerable periods. This is evident from the smoke stains on the roofs and also from the remains of ashes and cinders on the floors. In digging into some of these floors, fragments of the bones of animals, broken implements such as tomahawks, knives[1] and other articles used by the natives are found covered over with ashes and other *débris*, in some instances to the depth of one or two feet. These shelters are mostly found in the proximity of streams of a more or less permanent character, from which water was probably obtained for camp use during the occupancy of the cave. Very small shelters would obviously be unsuitable for residential purposes.

[1] See my paper on "Stone Implements Used by the Aborigines of N. S. Wales," *Journ. Roy. Soc. N. S. Wales*, xxviii, p. 304, Pl. xliii, Fig. 2.

Most of the paintings are executed on the cave walls, but they are not infrequently drawn on the roofs, and are sometimes found in both these positions in the same cave. They are generally within the reach of an individual standing on the ground, but in a few instances I have found them at heights varying from eight, twelve and eighteen feet above the floor. In such cases it is likely that the natives stood on ledges of rock which have since weathered away, or on a staging erected for the purpose.

These paintings are nearly always drawn on the natural surface of the rock, but in some cases I have found that the cave wall had previously been painted a different color to that employed in the figures executed upon it. In one case the wall had first been colored red and on this background the figures had been drawn in white.[1] A similar instance of white painting on a ground of red ochre rubbed on the cave wall is mentioned by Capt. P. P. King[2] as having been observed by him in 1821 at Clack's Island, Prince Charlotte's Bay, Queensland. Capt. Grey states that the rock around one of the figures seen by him in West Australia in 1838 was painted black in order to produce the greater effect.[3] In some of the caves visited by me I found that the walls had been blackened before the paintings were made upon them.[4]

Owing to the weathering of the cave walls, in some instances the paintings are barely discernible; and in such cases I have found that one can see them better by standing several yards off than when very close to them. It is well to observe them from more than one standpoint, so that they may be seen with the light falling upon them in different directions, for the purpose of bringing into view faint lines which might otherwise escape notice.

Throughout my observations respecting this subject I have found that the natives in selecting rock shelters in which to produce their paintings always chose those whose walls consisted of smooth surfaces on which the objects could be delineated and at the same time sufficiently hard to be durable. Caves consisting of soft, friable sandstone, or which were situated in damp localities, or were exposed to storms, were rejected as unsuitable. I have also found that far the greater number of these shelters have a northerly aspect,

[1] *Proc. Roy. Geog. Soc. Aust.*, Q. Branch, x, p. 65, Pl. ii, Fig. 8.

[2] *Survey Intertropical Coasts of Australia*, ii, pp. 26, 27.

[3] *Two Exceds. N. W. and W. Australia*, i, p. 202, Fig. 1.

[4] *Jour. Anthrop. Inst.*, xxv, pp. 157, 158, Pl. xiv, Fig. 2.

thus receiving more or less of the sun's rays on every sunshiny day. In the large number of these rock shelters inspected by me those which were the most exposed to the sun's rays were the best preserved; and it would appear from the fact that most of them face the direction of the sun that this was known to the aborigines.

Aboriginal rock paintings have been executed in three different ways, viz., stenciled, impressed and outlined. 1. In the stencil method the extended hand was placed firmly on the smooth surface of the rock and the required color blown or squirted over it out of the mouth. Sometimes the rock was first wetted and the color blown in a dry state around the object; in other instances the color was wetted and was then squirted out of the mouth. Drawings done in the last-mentioned way can be easily distinguished from those stenciled with dry powder. This method of drawing was also frequently used in representing native weapons such as tomahawks, boomerangs, waddies, etc. Small animals such as fish, human feet and the feet of animals are also sometimes shown in this way. The color in some of the larger figures appears to have been applied in a wet state with a tool similar to a brush or mop.

In many of the stenciled pictures of the hand it is probable that the latter was held in position on the rock and the color applied by the same individual; but in representations of feet and native weapons, some of the latter being three or four feet in length, it would be necessary for two or more persons to participate in the work. A modification of this method was to previously color the surface of the rock and afterwards to stencil the hand or other object upon it in a different color. This mode of drawing was very effective, especially when the ground was red and the stenciling was done in white.[1]

Stenciled drawings of the shut hand are occasionally met with. In these cases the hand with the fingers shut, but the thumb extended was placed against the rock and stenciled in the usual way.

2. In the impression method the palm of the hand of the artist was either rubbed over with a liquid color or was dipped into it, and while wet was firmly pressed against a smooth surface on the cave wall. Upon removing the hand, the colored impression of it was left clearly defined upon the rock.

[1] For an example the reader is referred to the cave described by me in the *Proc. Roy. Geog. Soc. Aust.*, Q. Branch, x, pp. 46–70, Pl. ii, Fig. 8.

A variation of this method of drawing was to impress the hand in the manner described and before removing it from the rock to squirt a different color around its margin. This may be more correctly called a combination of the impression and stencil methods.

In the districts visited by me in collecting information on this subject I have found impressed hands[1] in comparatively few caves, the stencil method being that generally adopted. It may be that impressed hands had some particular meaning. In both these methods of drawing it was always the palm and never the back of the hand which was used.

3. Objects which could not be either stenciled or impressed, such as men, animals and a number of nondescript figures and devices appearing on the walls of these rock shelters, have been drawn in outline in the color selected for the purpose. In some cases the objects are shown in outline only; in other instances the space within the outline is painted with a solid wash of the same tint; whilst not infrequently this space is shaded by means of lines drawn either all in the same color or in two or more different tints.

It is not very clear what the nature of the coloring matter was in all instances, but it undoubtedly possessed the durability of an ordinary pigment. In the drawings which appear in red there is no doubt that most of them are done with red oxide of iron, found as a clay and known as red ochre. The white color would probably be pipe clay or fine white ashes from the camp fire. The few drawings done in yellow are produced by an oxide of iron found as a clay in the same districts where the pipe clay and red ochre occur. The black color appears to have been done with charcoal or soot.

In cases where it was necessary to use any of these colors in a liquid form they were first reduced to a powder and were then mixed with water or with oil obtained from some animal. When applied in a dry state a piece of the required color, as a lump of red ochre, or pipe clay, or charcoal, was held in the hand of the operator and the necessary lines drawn with it upon the rock, the surface of which was probably first moistened with animal fat or water

[1] The earliest reference I can find to the "impression method" is that by Sir George Grey. He states that in a cave in the district of York, West Australia, there is "the impression of a hand which had been rubbed over with red paint . . . . and then pressed on the wall" (*Two Expeds. N. W. and W. Australia* (1841), Vol. i, pp. 260, 261).

along the outline of the figure to be drawn, which would have the effect of assisting the color to penetrate it.

Whether the color was applied as a liquid or a solid, water or grease appears to have been employed to work it into the surface of the stone and give it greater permanency. This is easily demonstrated by rubbing the figures with a wet cloth, which has no effect upon them; but if the same test be applied to the initials of white visitors written with chalk or charcoal in some of the shelters they rub off at once.

Vegetable colors were also known to the aborigines. Mr. E. Stephens says[1] that the natives of the lower Murray river and Adelaide plains painted red bands on their shields by means of the juice of a small tuber which grew in abundance in the bush. Sir George Grey stated[2] that he imagines that the blue color used in paintings seen by him on the Glenelg river in West Australia was obtained from the seed vessels of a plant very common there, which on being broken yielded a few drops of a brilliant blue liquid. I have myself stated[3] that the apple tree and also the grass tree of Australia yield a red gum or resin, which has the property of staining anything a red color.[4]

Explanation of Plate X.

All the figures represented on this plate are drawn to scale from careful sketches and measurements taken by myself, and the position of each cave on the public maps is accurately described by reference to the nearest purchased land in the vicinity. All the caves are in New South Wales.

Cave 1 consists of a weather-worn cavity in a large boulder of Hawkesbury sandstone within Portion No. 6, of fifty and three-quarters acres, in the parish of Bulga, county of Hunter. The interior is forty-two feet long, seventeen feet from the front to the back wall and eight and a half feet high. It faces S. 70° E., and has apparently been used as a camping place by the aborigines.

[1] *Jour. Roy. Soc. N. S. Wales*, xxiii, p. 487.

[2] *Two Expeds. in N. W. and W. Australia*, i, pp. 262, 263.

[3] *Proc Roy. Soc. Victoria*, vii, N. S., p. 146.

[4] Mr. E. M. Carr mentions that the natives of the Leichhardt river, Queensland, imprinted their hands, stained with red ochre or blood, on a conspicuous tree (*The Australian Race*, ii, p. 301).

The plate shows four hands—one of them being the right—done in white stencil. Amongst these is a human figure in black outline filled in with shading of the same color. There is permanent water in Wareng creek, five or six chains distant.

Cave 2 is situated within Portion No. 41, in the parish of Coolcalwin, county of Phillip, about ten chains from Jolly's Downfall creek, in which water is permanent. The cave is in a large isolated sandstone boulder, near the base of a rocky spur, and the entrance faces the northwest, so that it gets the afternoon sun throughout the year. Its length is fourteen feet, depth eighteen feet, with a height at the entrance of three feet, which increases to five and a half feet inside. The rocky floor has several natural interstices extending the whole length of the cave, with a few others nearly at right angles to them, caused by the disintegration of the softer parts of the sandstone, giving the floor the appearance, at first sight, of having been paved.

All the drawings in this cave, except the turtle, are executed in the stencil method, in red color. There are fourteen hands, several of which have some of the fingers missing; two are smaller than the rest; and in one the arm is shown nearly as far as the elbow. There is a rude representation of what may be either a turtle or a beetle, outlined in black and filled in with a wash of white. A child's right foot and two small bent objects complete the drawings.

Cave 3. This rock shelter is on Portion No. 81, of one hundred and eight acres, parish of Bulga, county of Hunter. Its length is fifty-four feet, depth eleven feet, and its height varies from four and a half to six and a half feet—the roof being level, but the floor irregular. The cave faces N. 20° E., and looks out upon a small watercourse. These drawings are all upon the roof, and are done in white stencil. They consist of eleven hands, one of which is very small; two native tomahawks with handles attached, and two other weapons. The position of the hands as well as the weapons is unusual and were probably intended to convey some meaning.

Cave 4. This cave is situated within Portion No. 31, of sixty-one and a half acres, parish of Merroo, county of Cook, near the right bank of a small gully in which water can be obtained during the winter months. It has been worn out of a low escarpment of Hawkesbury sandstone and faces the west; its length is twenty-three and a half feet and the depth eleven feet. Owing to the dome-shaped roof, the height inside is seven and a half feet, whilst that at the entrance is only five feet.

The drawings consist of a number of hands, ten of which are still distinguishable; one tomahawk with handle, and three boomerangs—all executed in white stencil. There is also a drawing which appears to be intended for a snake or an adder, and eight iguanas, varying in length from two feet to three and a half feet. The snake or adder and the iguanas are drawn in black outline, shaded with a wash of the same color within their margins.

NOTE.—I wish to make the following corrections in my paper on "Australian Rock Carvings," published in the PROCEEDINGS of this Society, Vol. xxxvi, No. 155:—

At page 200, line 5, for "western" *read* "northern."

At same page, line 6, for "No. 23" *read* "No. 83."

At page 203, line 8, for "portion" *read* "position."

At page 205, line 20, for "lind" *read* "line."

Figs. 39, 42 and 43, are on the same rock as Fig. 26.

Stated Meeting, December 3, 1897.

Vice-President PEPPER in the Chair.

Present, 19 members.

Mr. George Vaux, Jr., and Mr. William Tatham, newly elected members, were presented to the presiding officer, and took their seats.

Mr. Edmunds, by unanimous consent, offered the following:

Resolved, That a Committee of five members be appointed by the Chair to report as soon as may be, such further amendments to those proposed by the Committee reporting the Laws now under consideration, as shall by them be deemed best, and especially to provide for a separation of the Laws of the Society required by its Charter, from the regulations of administration and order which need not be in its Charter Laws, and that meantime the proposed revision of the Laws now pending, stand over from stated meeting to stated meeting until disposed of.

Adopted.

The Chair appointed the following as the Committee: Hon George F. Edmunds, William A. Ingham, Esq., William P. Tatham, Esq., Samuel Dickson, Esq., and Richard L. Ashhurst, Esq.

Donations to the Cabinet and Library were announced, and thanks were ordered for them.

The death of Dr. George H. Horn, on November 24, 1897, æt. 58, was announced.

The following papers were read by title, as follows:

"The Passamaquoddy Wampum Records," by J. Dyneley Prince, Ph.D.

"The Ethnic Affinities of the Guetares of Costa Rica," by Daniel G. Brinton, M.D.

"The Sources of Goethe's Printed Text: Hermann and Dorothea," by Prof. W. T. Hewett.

Mr. McKean read the reports of the Committee on the Henry M. Phillips Prize Essay Fund and of the Trustees of the Building Fund.

Dr. Frazer made a communication, illustrated by photographic views, on "The Ourals and the Caucasus."

The annual reports of Treasurer and Finance Committee were read.

The rough minutes were read, and the Society was adjourned by the presiding officer.

THE PASSAMAQUODDY WAMPUM RECORDS.

BY J. DYNELEY PRINCE, PH.D.

(Read December 3, 1897.)

The Passamaquoddy Indians of Maine, who, together with the Penobscots, now occupy Oldtown on the Penobscot river as their headquarters, are members of the great Algonkin family which was in former times the dominant native race from Nova Scotia to the Carolinas. The language still in use among the Passamaquoddies[1]

[1] The Indians call themselves *Pestumagatiek* in their own idiom.

is a northern dialect of the Algonkin stock, very closely allied to the idiom of the Etchemins or Maliseets of New Brunswick and to that of the Abenakis[1] or St. Francis Indians of Quebec, and less closely, although nearly, related to the language of the Micmacs of Nova Scotia.

The Passamaquoddies, Penobscots, Maliseets, Abenakis and Micmacs call themselves by the common name *Wabanaki* or "children of the dawn-country,"[2] which was in earlier days the generic name of the entire Algonkin family. These five tribes seem to have been members of a federation both with one another and with the Iroquoian Six Nations, and the Passamaquoddies have preserved the traditions regarding both of these unions in their Wampum Records, the text and translation of which are given in the present article.

The records of an Indian tribe were in nearly all cases orally transmitted by elderly men whose memories had been especially trained for the purpose from their early youth. It was customary for these keepers of the tribal history from time to time to instruct younger members of the clan in the annals of their people. The records thus transmitted in the case of the Passamaquoddies were kept in the memory of the historians by means of a mnemonic system of wampum shells arranged on strings in such a manner that certain combinations suggested certain sentences or ideas to the narrator or "reader," who, of course, already knew his record by heart and was merely aided by the association in his mind of the arrangement of the wampum beads with incidents or sentences in the tale, song or ceremony which he was rendering. This explains such expressions as "marriage wampum" or "burial wampum," which are common among the Passamaquoddies and simply mean combinations of wampum which suggested to the initiated interpreter the ritual of the tribal marriage and burial ceremonies.

This custom of preserving records by means of a mnemonic system was peculiar to all the tribes of the Algonkin race as well as to the Iroquoian clans. Brinton refers to the record or tally sticks of the Crees and Chipeways as the "rude beginning of a system of mnemonic aids."[3] It seems to have been customary in early times

[1] The Abenakis who call themselves *Wabanaki* are at present a small clan resident at St. Francis near Quebec. They were at one time a powerful New Hampshire tribe.

[2] See Brinton, *The Lenape and Their Legends*, p. 19.

[3] *l. c.*, p. 59.

to burn a mark or rude figure on a stick suggestive of a sentence or idea. Brinton adds:[1] "In later days, instead of burning the marks upon the stick, they were painted, the colors as well as the figures having certain conventional meanings. The sticks are described as about six inches in length, slender, although varying in shape, and tied up in bundles." Among the more cultured tribes the sticks were eventually replaced by wooden tablets, on which the symbols were engraved with a sharp instrument, such as a flint or knife. The Passamaquoddies appear never to have advanced beyond the use of wampum strings as mnemonic aids.

I obtained the Wampum Records at Bar Harbor, Me., in 1887, from a Passamaquoddy Indian, Mr. Louis Mitchell, who was at that time Indian member of the Maine Legislature.[2] The MSS. which he sent me contained both the Indian text and a translation into Indian-English, which I have rearranged in an idiom I trust somewhat more intelligible to the general reader. Owing to the fact that the Indian text in Mitchell's MSS. is written syllabically, without any attempt at a division into words, much less into sentences or paragraphs, the difficulty of editing the same with even approximate correctness has been very great. I have followed almost exactly Mr. Mitchell's extremely variable orthography, although tempted in many cases to depart from it, as he has written what is evidently the same sound sometimes in as many as three different ways. Thus, he was clearly unable to distinguish between *j* and *ch*, *a*, *u* and *e*, or *oo* and *u*, and he uses *k–c*, *kw–qu*, *b–p*, etc., apparently indiscriminately. I plead guilty in advance, therefore, to any errors which may occur in the original text, trusting that the interesting character and historial value of the records themselves will justify their publication in the state in which I offer them.

[1] *l. c.*, p. 59.

[2] The Passamaquoddy and Penobscot tribes send a representative to the Maine Legislature who is permitted to speak only on matters connected with the affairs of the Indian reservations.

The Wampum Records in Passamaquoddy.

Mechi mieu begokni tohocioltowuk k'chi ya wioo w'skittap epitjik wasisek nespi w'sikyojik yot mechi mipniltimkil; nitt etuch alitt-huswinook negmaoo tepit-hodmotit chewi kegw layoo kegu-sitch eliyoek chewi layoo tech na neksayiu. Nitt etuchi m'sioo sise p'chittaketil kinwetaswinoo m'sitte elipitt w'skichin anquotch elquiyik sownisnook anquotch w'chipenook ketkik snoot segdenook ketkik k'ski yasnook. Pechiote pechiyik Wabnakik. K'mach w'sipkikm'n yaka keswook naga wew'chiyanya nitta tama weji-wetit w'tiyawa w'skichunoo kepechip-tolnen w'liagnotmag'n. N't ettlowsittgw-ton kisipootwusoo likislootemook. M'sitte tekepitt w'skichin kinwetto nitt k'chi lagootwag'n kitwitasso. M'sioo w'skichin nootek aknoomag'n m'sioo w'litt-hasoo. M'sioo w'si-watch yogonyalkatkisilet tekowm'k maltnitin. Nitt m'sioo kesook-mik sittobjitakan opootwuswinoom. M'sioo kesookmik sittopetchi-takan nissoo kessena agwam'k opootwuswinoom natchiwitchitagwik k'chi lagootwag'n kessena k'chi mawopootwuswag'n.

Nitt m'sioo kisma wewsettil nitt omache tipit-hodm'nya ta n'teh w'telook-h'dinya. Stepal m'sioo siwatch yokotit eli w'abli pemow-sittit; yotk k'chi sogmak w'tiyana-k't kihee yot elapim'k asitt-wechosyokw k'n'mittunen elipegak napttwuk kenemittonenwul kesek ewablikil yot'l pegaknigil tem'hig'nsis'l to (?) naga tapyik tepakw-yil chewi pooskenoswul oskemioo nitte m'sioo w'tlikis-lootm'nya w'tlagootinya; nitt otaginwipoonm'nya kisook etuchi pootwusitit.

Nitt liwettasoo chikte wigwam. Yot w'kesekmenya etasikiskakil katama loo-wen-kelosioo m'sitte pootwuswin chewitpit-hasoo tanetch w'titm'n. Tan etuchi littootit tebaskuswag'n'l m'sitte w'tipit-hodm'nya tanetch likisi-chenetasso man'tim'k guni chikpultowuk topemlokemkil.

Apch etuchi apkw-timootit wigwam liwitassoo m'sittakw-wen tlewestoo nitt na guni omache pootwuswinya; m'sioo potwooswin w'toknootm'n elippipyaks nage mech matnuttitit m'sioo eli w'sik-yoltotitits guenipn'ltim'k; nittlo alteketch tepnasko yotipit-hatosoo naga k'temakitt-haman w'tepittemowa w'towasismowa nega mamat-wikoltijik; mechi mieu yokli-w'sikyaspenik tahalote saglit-hat w'sikap naga m'tappeguin. Nitt m'sioo mitte westotitit. Nitt likisloomuk w'tlitonia k'chi lakalosnihag'n naga tochioo opoom'nya

The Wampum Records in English.

Many bloody fights had been fought, many men, women and children had been tortured by constant and cruel wars until some of the wise men among the Indians began to think that something must be done, and that whatever was to be done should be done quickly. They accordingly sent messengers to all parts of the country, some going to the South, others to the East, and others to the West and Northwest. Some even went as far as the *Wabanaki*.[1] It was many months before the messengers reached the farthest tribes. When they arrived at each nation, they notified the people that the great Indian nations of the Iroquois, Mohawks and others had sent them to announce the tidings of a great *Lagootwagon* or general council for a treaty of peace. Every Indian who heard the news rejoiced, because they were all tired of the never-ending wars. Every tribe, therefore, sent two or more of their cleverest men as representatives to the great council.

When all the delegates were assembled they began to deliberate concerning what was best to do, as they all seemed tired of their evil lives. The leading Chief then spoke as follows: "As we look back upon our blood-stained trail, we see that many wrongs have been done by all of our people. Our gory tomahawks, clubs, bows and arrows must undoubtedly be buried for ever." It was decided, therefore, by all concerned to make a general *Lagootwagon* or treaty of peace, and a day was appointed when they should begin the rites.

For seven days, from morning till night, a strict silence was observed, during which each representative deliberated on the speech he should make and tried to discover the best means for checking the war. This was called the "Wigwam of Silence."

After this, they held another wigwam called *m'sittakw-wen tle-*

[1] According to Indian tradition, six Iroquoian tribes united in a confederation in the interests of peace. This was the famous league of the six nations: Onondagas, Mohawks, Oneidas, Senecas, Cayugas and Tuscaroras. The first five of these completed their league as early as the middle of the fifteenth century under the Onondaga chief Hiawatha. The object of the federation was to abolish war altogether (see Brinton, *The American Race*, pp. 82, 83). It is evident that the Passamaquoddy tradition embodied in this part of the Wampum Records refers to these proposals made by their Iroquois neighbors.

epasioo k'chi wigwam tebagalosneoo; na w'tlitunia ebiss oponmoonya omittakw-sowall nitt wen pelestowatt nitt etuch eshemhoottam yot'l eyilijil w'nijan'l tebakalusneoo. M'sitte na w'tachwiyik settswawall naka na mejimioo w'm'tutwatm'n w'kchi squt wa wechi skanekaswenook. Yot wechi mach-hak wababi tebaskuswag'n'l.

Nitt lagalosnihag'n'l ettli-n'settwasik spemek nitt nitmame lagootwi-kislootmewag'n m'sitte kesigpesitt w'skichin newanko kesookinito kenooklo kechayami milijpesw. M'sitte yokteke w'skichinwuk w'tachwi elyanya naga wiginya tebagaloosneoo teketch wen kegw liwableloket chiwisemha w'nikikowal w'tesemhogol; nitt ebis kisi mawettasiks nittlo tane teppo wigitt tebakalosneoo chejik s't'menal tan eyigil tebaskuswag'n'l kessena essemha. Nitt wigwam ettlinwasik tabakalosneoo hidmowioo m'sitte kesitt w'skichin kesittakw chewi sanke wipemowsoo. Katama apch chigawi yotoltiwun chewi lipemowsowuk tahalo wesi westoltijik witsegesotoltijik opeskon wenikicowa. Nittlo k'chi squt ettli w'sittwasik wigwamek hidmowiw m'sitte ta wut kiswichitakw w'skichin nittetch ettlositit squtek wela manch skat apch teke yiwibmes-honwal. Nittlo wenikigowal ettlin m'sitt woot wigwamek nitt k'chi Sagem Kanawak. Nitte lakaloshig'n naga hibis hidmowiw wababi tebaskuswag'nl. Tan wut pelsetek chewi mawe sagyawal ettli n'settwojik nitt m'sigekw kisittpiyak.

Nitte apch omach elok-h'dinya h'n'w'tlitunia apsegiguil w'tebaskuswag'nowal. M'sioo yot'l tebaskuswag'n'l chewi-littaswul wababik. Wechich kiskittasik tan teppo elikimwittpiyak elnogak m'sittech yo naga elimilichpegek wapap. Yot wapap elyot sagmak naga m'itapeguinwuk naga nipwultimkil. Elok-h'dimek tane etuchi metchmete sagem naga elipuskenoot eli-m'takittmowatil m'sitte w'skichinwuk. Wulasikowdowi wapap; wigwamkewi wapap.

westoo, or "Wigwam of Oratory." The ceremonies then began. Each representative recited the history of his nation, telling all the cruelties, tortures and hardships they had suffered during their wars and stating that the time had now come to think of and take pity on their women and children, their lame and old, all of whom had suffered equally with the strongest and bravest warriors. When all the speeches had been delivered, it was decided to erect an extensive fence and within it to build a large wigwam. In this wigwam, they were to make a big fire and, having made a switch or whip, to place "their father" as a guard over the wigwam with the whip in his hand. If any of his children did wrong he was to punish them with the whip. Every child of his within the enclosure must therefore obey his orders implicitly. His duty also was to keep replenishing the fire in the wigwam so that it should not go out. This is the origin of the Wampum laws.

The fence typified a treaty of peace for all the Indian nations who took part in the council, fourteen in number, of which there are many tribes. All these were to go within the fence and dwell there, and if any should do wrong they would be liable to punishment with the whip at the hands of "their father." The wigwam within the fence represented a universal house for all the tribes, in which they might live in peace, without disputes and quarrels, like members of one family. The big fire (*ktchi squt*) in the wigwam denoted the warmth of the brotherly love engendered in the Indians by their treaty. The father ruling the wigwam was the Great Chief who lived at Caughnawaga. The whip in his hand was the type of the Wampum laws, disobedience to which was punishable by consent of all the tribes mentioned in the treaty.

After this, they proceeded to make lesser laws, all of which were to be recorded by means of wampum, in order that they could be read to the Indians from time to time. Every feast, every ceremony, therefore, has its own ritual in the wampum; such as the burial and mourning rites after the death of a chief, the installation of a chief, marriage, etc. There were also salutation and visiting wampum.

Elok-h'dim'k tan etuchi mechmete Sagem.

Tan etuchi mechinett sagem omutl'waqulm'n'l chewi temitaha naga n'kikw-wakw-san. M'sitte tan kesiyitt w'towegaknul w'tchapyil w'tumhigen naga w'mutewag'n w'skichinwuk w'nittagitmowawal enguchi g'dunweyin. Tan etuchi tepnasgoyak w'skichinwuk wikwmania pootwuswinoowo pootwuswinia wateplomania pili sagmal negootekmi katama w'kislomowyil sagmal. Nitte eli kisi-mawekislootmootitits nitt opechitakaya kinwetasswinoo newunol kessena kamachin hegwitnol hesgun elye Mikmakik, Kebeklo, Panwapskek welastogok sagem teli mechinett Pastemogatiek. Tan etuchi pechiyatit kinwettasijik elyatit Mikmakik nitte m'mittutil wechkiyak eguidin metenegnahasik w'kisin setumenya kigw ittmowio nitte sagem w'moweman oskmaknesum w'tiyan nitt wechkoyak kigw nitk kinwut wechipechijik. Nitt m'sitte wen wasisek nake epijik w'skittapyik m'tappyataswook wenachi asikwenya malemte eguayik. Nitte peskw w'gapetasin natuchio w'tlintowatmun n'skawewintowag'n'l. Nitt w'tali esui n'skawan elamkigap wiyalit. Malem te mechintoo nitte na yok wechiyojik peskw littposwin omilawiyan nitt na negum w'tasitetunan w'siwesul na negum w'wuskawan.

Malem te m'sioo mechi n'skaw-h'timek naga tuchioo omach yapasinya imye-wigwam'k w'naji mawehimyanya. Malem tech apch kisi-myawletwuk naga tuchioo lippan tanpunote wigwam'k. Nitt m'sioo wen peji ti epijik wasisek m'sioo w'tlapasinya w'naji w'lasikwawa s'sikiptinenawa naga na opummumya m'tewegon tesagioo wigwam'k ettli wechiwetit nitt naga tojio kchi-yawiwul w'skichin wutakewag'nl.

Elukemkil etchwi kisetuchil meskw kisi sepyatikw nitt amskwas welaguiwik eh'li wulit-has soeltowegw pemgowlutwuk. Nitt apch wespasagiwik yotk mejiwejik opetchitaganya pesgowal oskittapemwal sagmawigwam'k wutiyanya sagmal opawatmunia m'sitte w'unemyanya oskittapi gwandowanek. Nitte sagem w'takinwettuwan oskittapemomaweman gwandowanek naga apch w'taginwettuwan yohote wechi-welijihi. Nitt na kisi kusyapasitit naga tojoo omoosketunia wapapyil naga tojoo egitoso negett elikislotmotits. Nitt ettlowsitt Pestumagatiek w'kuskatam w'k'chi-w'skinosismowow; nittlo k'pawatmag'nkil yot ettlowsiyan k'najiwichi kehman eliat-k'chi'w'-skinosismul. Malem te nega kise westoltitit yotk wechiwejik nitt

Ceremonies Customary at the Death of a Chief.

When the chief of a tribe died, his flag-pole was cut down and burnt, and his war-like appurtenances, bows and arrows, tomahawk and flag, were buried with him. The Indians mourned for him one year, after which the *Pwutwusimwuk* or leading men were summoned by the tribe to elect a new chief. The members of one tribe alone could not elect their own chief; according to the common laws of the allied nations, he had to be chosen by a general wigwam. Accordingly, after the council of the leading men had assembled, four or six canoes were dispatched to the Micmac, Penobscot and Maliseet tribes if a Passamaquoddy chief had died.[1] These canoes bore each a little flag in the bow as a sign that the mission on which the messengers came was important. On the arrival of the messengers at their destination, the chief of the tribe to which they came called all his people, children, women and men, to meet the approaching boats. The herald springing to land first sang his salutation song (*n'skawewintuagunul*), walking back and forth before the ranks of the other tribe. When he had finished his chant the other Indians sang their welcoming song in reply.

As soon as the singing was over they marched to some *imwewigwam* or meeting house to pray together. The visiting Indians were then taken to a special wigwam allotted to their use over which a flag was set. Here they were greeted informally by the members of the tribe with hand-shaking, etc. The evening of the first day was spent in entertaining the visitors.

On the next day the messengers sent to the chief desiring to see all the tribe assembled in a *gwandowanek* or dance-hall. When the tribe had congregated there, the strangers were sent for, who, producing their strings of wampum to be read according to the law of the big wigwam, announced the death of the chief of their tribe, 'their eldest boy" (*ktchi w'skinosismowal*), and asked that the tribe should aid them to elect a new chief. The chief of the

[1] From here on the recorder mentions only the neighboring Algonkin tribes as belonging to the federation which he has in mind. The northern Algonkin tribes were very probably in a loose federation with the Iroquois merely for purposes of intertribal arbitration. These Algonkin clans themselves, however, seem to have been politically interdependent, as one clan could not elect a chief without the consent of all the others.

na sagem onakisinn na wutelewestoon w'tiyan w'pemowsowinoom nitt negum holithodmun wenajiwi-chakekemiw wicho keman w'siwesul kipnael. Nitt apch yotk wechiwejik onagesin w'teleweston olasweltum'n kisi weleyet sagman eliwulmatulit napch okisiyinya nega tojoo onestom'nya kisookch etuchiweswesittit.

Wechiyowitit nittech apch liwitasso eldagemk ekelhoochin malem te kisachwuk weswesinya. Wechiyawitit nitt sagem w'tokinwettuwan oskittapem nitk k'siwesnowook kisachwuk weswesinya katama kiseltumwownewin toji neksayiu omach-honya. Napch moskettaso wapap kelhodwei naga w'tegitmunya w'tiyawa: n't yot etlowsit Mikmakik epit wasis w'skittap k'powatmagon k'chenesin apch wagisook nio nitt kigwusin katagonkuthag'n k'machkulit-hookowa. Nitt ittmowioo katama okiseltumwawun omach-halin.

Nitt apch elok-h'dim'k liwitasso n'skowh'din. Nitt apch sagem opechitagon oskittapem onachi ketonkatinya k'chikook nitt appi k'tunkatitit nitt w'telogw-sumnia tan eli pechputit m'sioo weyesis nepahatijihi malem te m'sioo kegw kisogwew. Nitt m'sioo macheptaso gwandowanek nitt ettli kitimawemittsoltitit naga kinwetowan nojikakolwet (*or* notgudmitt) w'talqueminowticook k'waltewall (*or* wikw-poosaltin). Nitt m'sioo wen w'nastowan. Elque milit nitte na w'quaskoltinya wasisek epitjik w'skitapyik pemip-hatijihi waltewa mosque weya malem te pechik sikowlutwuk gwandowanek. Nitte m'sioo t'holpiyanya pemkemigek nitt yotk nojitophasijik otephemwan yayate elapesitt. Yot nitt elwittasik elok-h'dim'k egelhodwi wikw-paltin; nitt kisapeseltitit omach yapasinya. Nitte apch neksayiu appat aptdoowuk. Nitt naga tochio h'nskowh'din nitt apch yotk wechiwejik onakisin peskw w'tlintowatm'nhichi eleyiks elittotits omesomsowuk peskwun kessena nisnol elintowatkil. Nitt na sagem wut wechi yot wenaskawan-na.

Malem te nitt mechintotim'k nitt sagem holpin eppasio gwandowanek kelnek pegholagnesis naga epesis nitte omache k'tumosin omachetemun opekholag'n naga otlintowatmun k'tumaswintowag'n'l. Nitt miswen onayinyan opemkan w'skittapyik epitjik pechiote wasisek nitt omikmow powl'tinya.

Nitt malem te mechitt piye apch naga tojoo apch otakinwipunmunia etuchi mach-hatit. Apch kisatchitit nitt apch sagem nimwul-k'd'minya hilelok-h'dimkil. Anquotch metch nichi kesspemi minwukelhak yot nitt eldakewag'n anquotch metch nihilente stranger tribe then arose and formally announced to his people the desire of the envoys, stating his willingness to go to aid them, his fatherless brothers, in choosing a new father. The messengers, arising once more, thanked the chief for his kindness and appointed a day to return to their own people.

The ceremony known as *kelhoochun* then took place. The chief notified his men that his brothers were ready to go, but that they should not be allowed to go so soon. The small wampum string called *kellhoweyi* or prolongation of the stay was produced at this point, which read that the whole tribe, men, women and children, were glad to see their brothers with them and begged them to remain a day or two longer; that "our mothers" (*kigwusin*), *e. g.*, all the tribal women, would keep their paddles yet a little while. This meant that the messengers were not to be allowed to depart so soon.

Here followed the ceremony called *N'skahudin.* A great hunt was ordered by the chief and the game brought to the meeting-hall and cooked there. The *noochila-kalwet* or herald went about the village crying *wikw-poosaltin,* which was intelligible to all. Men, women and children immediately came to the hall with their birch-bark dishes and sat about the game in a circle, while four or five men with long-handled dishes distributed the food, of which every person had a share. This feast was called *kelhootwi-wikw-poosaltiu.* When it was over the Indians dispersed, but returned later to the hall when the messengers sang again their salutation songs in honor of their forefathers, in reply to which the chief of the tribe sang his song of greeting.

When the singing was over the chief seated himself in the midst of the hall with a small drum in one hand and a stick in the other. To the accompaniment of his drum he sang his *'k'tumasooi-n'ta-wagunul* or dance songs, which was the signal for a general dance, followed by another feast.

The envoys again appointed a day to return, but were deterred in the same manner. As these feasts often lasted three weeks or a month, a dance being held every night, it was frequently a long time before they could go back to their own tribe, because the chief kessena te peskw kisus etasi-welaquiwigil pemkak; nitt quenni wechi yot.

ELOK-H'DIM'K TAN ETUCHI ELYOOT SAGEM.

Malem te m'sigekw mitnaskiyi nitt naga toji sankiyiw omaja hapanya malem tech nitk pechiyik elyatit wecheyawitit nitte na omawemania opemowsowinomwa w'teginwetowania eli kisi-kiwkenitit eli pekwatotit wichoketwag'n. Miyawal te nitk na ketkik otapch-yanya ki w'kenitsepenik. Nitt w'chi-mach-yiw otaskowalmunia wechiyan nachiwichi sakmakatenik. Malem te pechiyik om'sioo nitt me (?) elok-h'dimkil-lelan nach sekeptin ewan nut pemkemek. Pechiyatil odenesisek kisi-pemkatil kisi-n'skowh'ditit.

Malem te tama nisook nekiwik naga omache hel-yanya m'tewagem'l n't sagem kitwi yot om'tewagwemul. Malem te kisachitt otemepelanya h'nitt peskw sagmak oponmowan naga w'nasettowan omannim'l naga na onas-hewhotlanya pileyal elequotewag'n'l. Nitt peskw sagem onestomowan yohot sagmal kisiyajik wutege k'chi-w'skinosismowa k'tachwi elokepa tan eli kisi wulasweyekw naga na k'tachichik s't'wania nekemch na elookil tan wechi miyawil wahod opemowsowinoom. Yot'l na echwi elokejil sagem w'tachiwi sagitonel m'sioo tan yoot'l nekachikil. W'tachwi klamanel chikow yoot'l timkil matn'toltimkil w'tachwi na kig-ha opemowsowinoom. Chikate w'pemowsowag'n lawutik.

Napch omach yot asinya gwandowanek w'nachmoyowag'nya. Napch sagem w'kutomasin naga wisek-han sagmal sagmaskw wisekhod pili sagmal naka kiskamek.

Apch wespasakiwik naga okeptinen teboloman elwig'n'k keswuk nihitanke yachihi w'tliteboloma wataholoteh elitebolomoot sagem. Peskw na elipemket wut eli wisek-hot. Eli miloot o'manimwa aguami sagleyowal katik sagem napch wut piliwi sagem oskowiman naga onestomowan kesich pigak wutlokewag'nowal miyawal tena okisajin otewepoosan m'tewaguem. Nittle metewag'n-mel osagmamwal nitk gaptinek wiwunik apwihtowatijil ya te chikihig'n'l kelnajit ayat na tan teppo yot kegus ewabligik quasijik kemenia pekusek w'tachwi pekiyawal. Yot nitt itmowin w'tachiwi wulankeyowwowwal tan te quenowsiltil pemowsowag'nawa te w'tlipoonm'nia.

would detain them whenever they wished to return. Such was the custom.

The Ceremony of Installation.

When they reached home, however, and the embassies from the other *Wabanaki* tribes had also returned, the people of the bereaved tribe were summoned to assemble before the messengers, who informed them of the success of their mission. When the delegates from the other tribes, who had been appointed to elect the chief, had arrived and the salutation and welcome ceremonies had been performed, an assembly was called to elect the chief.

This took place about the second day after the arrival of the other *Wabanaki* representatives. A suitable person, a member of the bereaved tribe, was chosen by acclamation for the office of chief. If there was no objection to him a new flag-pole was made and prepared for raising, and a chief from one of the kindred tribes put a medal of wampum on the chief-elect who was always clothed in new garments. The installing chief then addressed the people, telling them that another "eldest boy" had been chosen, to whom they owed implicit obedience. Turning to the new chief, he informed him that he must act in accordance with the wishes of his people. The main duties of a chief were to act as arbiter in all matters of dispute, and to act as commander-in-chief in case of war, being ready to sacrifice himself for the people's good if need were.

After this ceremony they marched to the hall, where another dance took place, the new chief singing and beating the drum. A wife of one of the other chiefs then placed a new deer-skin or bear-skin on the shoulders of the new chief as a symbol of his authority, after which the dance continued the whole night.

The officers of the new chief (*geptins*) were still to be chosen. These were seven in number and were appointed in the same manner and with the same ceremonies as the chief. Their duties, which were much more severe, were told them by the installing chief. The flag-pole, which was the symbol of the chief, was first raised. The *geptins* stood around it, each with a brush in his hand, with which they were instructed to brush off any particle of dust that might come upon it. This signified that it was their duty to defend and guard their chief and that they should be obliged to spill their blood for him, in case of need and in defense of the

W'tachwi lipoonmenia opokenoom ya hotankeyowa tich-hi nihitanke yatgotachihi tan etuchi nesa naguak pechyamkotit. Chewi noteyik gaptinek wut sagem kislomot katama kiseltumwawun wichipnusin ansa teppo w'tankeyowa opemowsowinoom naga w'note genekmen tan gekw-nesanaguak pechiyak. Nitt wut sagem naga otelitepsowinoom okisitpesotinia.

Nitt apch ketkil elok-h'dimkil malem te nitt welaguiwik nitt yaka opemkanya tegio te apch echeguak enitespatek w'tenkamhedoltinia. Enowdoltowuk epeskum-h'dinya w'kisik-apwelanya metewagwemel. Nitt m'sioo tan elitowtoltitit ek-hodasik tan wut neglo-wechik niktech wikw-nekik niltelkisek hodasikil. Nitt elok-h'dim'k anquoch queneket nihi sente kessena te pes-kisoos.

Nibowe eldakewag'n n'kansoswei.

Tan etuchi w'skinoos pewatek oniswitijil en w'takin-wetowan w'nikigo naga tan yot'l pawatgil nika nio nitaskowtitiesil netch wut k'takw-hemoos w'takin-wetuwan w'telnapem nitt skawen waplit-hodmuk nittech tekw-chetunia. Nitt wut k'takw-k'moosimilan kelwasilipil pileyal mowinewiyul kessena odook kessena quabit-ewiyul. Nutch wut oskinoos omachep-hon odeneksonel yet nackskw wikowak netch nitponan wut neksonel nowtek wigwamek; yote ebonel nisnol naga nowtek naga k'soshone. Nitt elichpi milipitasik ela-wigwam nitt kisekelat w'doneksonel. Wut loo nackskw omitakw-sel otakin-wetuwan otelnapem malem te kisi mowemat w'nustowan eliwisilit w'skinosel pechipowat matonijanel w'niswinya. Nitt skawen wablitt-hodmuk nittech wut kitakw-p'moos w'telkiman w'tusel nowtek pemekpit eneksone nittech nitt kisitt piye nipwoltin nitan elikwusitasik wigopaltin mawemitsoltin ayot pemkamik neskow h'dim'k. Anquotch quenatk't pemlokemkil.

Nibowe eldakewag'n yote pilioo yot kisi mawetasik.

Tan etuchi w'skinoos ketwakatek w'tachwich na kinwettwa w'nikiko w'nostowan nackskwyil powatkil. Netch wut k'takw-hemoos omaweman w'telnapemwa nitt skatwen waplit-hodmuk. Nitch w'dakinwettowania nojikelol welijil nitch omacheptunia nequotatkeyi wapap nittech nitt milatit wut nackwesk omitakw-sel naga tan te kisikesitit kesosejihi najichik lutkig wapap egitasik nibowei. Liwitasso k'lelwewei yotech w'tetlegitm'n elgitnuwik w'nestowalch na eli-wisilit tribe. All the women and children and disabled persons in the tribe were under the care of the *geptins.* The chief himself was not allowed to go into battle, but was expected to stay with his people and to give orders in time of danger.

After the tribal officers had been appointed, the greatest festivities were carried on; during the day they had canoe races, foot races and ball-playing, and during the night, feasting and dancing. The Indians would bet on the various sports, hanging the prizes for each game on a pole. It was understood that the winner of the game was entitled to all the valuables hung on this pole. The festivities often lasted an entire month.

The Marriage Ceremony.

The Ancient Rite.

It was the duty of the young Indian man who wished to marry to inform his parents of his desire, stating the name of the maiden. The young man's father then notified all the relatives and friends of the family that his son wished to marry such and such a girl. If the friends and relations were willing, the son was permitted to offer his suit. The father of the youth prepared a clean skin of the bear, beaver or deer, which he presented to his son. Provided with this, the suitor went to the wigwam of his prospective bride's father and placed the hide at the back of the wigwam or *nowteh.* The girl's father then notified his relations and friends, and if there was no objection, he ordered his daughter to seat herself on the skin, as a sign that the young man's suit was acceptable. The usual wedding ceremonies were then held, viz., a public feast, followed by dancing and singing, which always lasted at least a week.

The Marriage Ceremony in Later Days.

After the adoption of the wampum laws the marriage ceremony was much more complicated.[1]

When the young man had informed his parents of his desire to marry and the father had secured the consent of the relations and friends, an Indian was appointed to be the *Keloolwett* or marriage herald, who, taking the string of wampum called the *kelolwawei,*

[1] Mitchell interpolated this remark.

oskinosel n't pawatek nit'l nackskwuyil oniswinya. Nittech nitt metewestakw nittech weswi yapasinia yot w'skinoos wigek. Nittec-et-tlaskowasooltitit tegio asittemoot. Nittech na wut nackskw omitakw-sel omaweman otelnapemw'l nittech skatwen wablit-hamagw nit'l pechi kelolwelijil nittlowen kegw k'chi chitwat ewabligik w'mestom'nch. Nittech sagesso k'tinipwooltimkepn. Nittlo m'sioo li wulit-hodmotit nitt etepkisitpiye. Nitt neke oskichinwuk kisi papatmotit nitch patlias onipwik-han.

Nittech nitt'l nibowe eldakewag'n'l elok h'dim. Wutech w'ski-noos omilwan pileyal elquootewag'n'l nitt kissewett wut pilkatek netch omach yapasinia oniswitijil wigwek netch w'natlasikwan w'niswitijil wenachi sekeptinenan w'niswitijil naga kesosejihi. Yot nitt eliwittasik eldakewag'n wulisakowdawag'n. Nitt weswesitt wikwak nutch nut holpiyanya yohot na pechi kesosejihi quesquesoos naga pilskwessis naga gana w'skittapyik. Wutech na w'skinoos na onag'nl ma keslasikasijihi nittech omach yapasinia w'nachi sekepti-nenya. Malem tech metlasikowdoltin. Nittech uletonya k'chi mawepoltimek wutech nackskw towipootpoonek liwitass natpoonan oskittapyik epijik pechi te wasisek. Wutech na w'skinoos soksagw kotch meketch tlagw-te mijwag'n malemch kisakw-tek. Nitt wiko-paltinya netch w'gagalwaltinya k'waltewall. M'sitte wen w'nestem nitt.

Nitt omache guaskoltinia natchi teppam wan wikopalan. Mechte nibowattimek meskw metekto. Nitte otlas-hewhodlusooltinya naga omach yapasinia gwandowanek. Malem te pachaswook gwando-wanek pechi kesosejihi. Nitte kes yapasitit nitte pesgowat pesku-tenil ech wechi k'chich yot lusoweskw eliyit kis gwandowanek. Nitt ne oskinoo-lusoo. Ena negum omach yapasinia kesooswechihi malem te petapaswuk kesyapasittit nitt apch peskw-tay peskowat. Nitte gaptin omachep-han omachi-ostook kegania oniswitijil.

Malem te epasitpokak en-onatpoon-h'dinya kiste wulaquipwag'n. Nitt etli mikomoot yotk kisiniswijik nitt yot'l lusowesquiwil omache kesoosanya k'chi epitjik. Otasohonel na onespiptonial.

Metegut.

went to the wigwam of the girl's father, generally accompanied by as many witnesses as cared to attend. The herald read the marriage wampum in the presence of the girl and her father, formally stating that such and such a suitor sought his daughter's hand in marriage. The herald, accompanied by his party, then returned to the young man's wigwam to await the reply. After the girl's father had notified his relatives and friends and they had given their consent, the wedding was permitted to go on.

The usual ceremonies then followed. The young man first presented the bride-elect with a new dress. She, after putting it on, went to her suitor's wigwam with her female friends, where she and her company formally saluted him by shaking hands. This was called *wulisakowdowagon* or salutation. She then returned to her father's house, where she seated herself with her following of old women and girls. The groom then assembled a company of his friends, old and young men, and went with them to the bride's wigwam to salute her in the same manner. When these salutations were over a great feast was prepared by the bride, enough for all the people, men, women and children. The bridegroom also prepared a similar feast. Both of these dinners were cooked in the open air and when the food was ready they cried out *k'waltewall* "your dishes." Every one understood this, which was the signal for the merry-makers to approach and fall to.

The marriage ceremonies, however, were not over yet. The wedding party arrayed themselves in their best attire and formed two processions, that of the bride entering the assembly wigwam first. In later times it was customary to fire a gun at this point as a signal that the bride was in the hall, whereupon the groom's procession entered the hall in the same manner, when a second gun was fired. The *geptins* of the tribe and one of the friends of the bride then conducted the girl to the bridegroom to dance with him. At midnight after the dancing a supper was served, to which the bride and groom went together and where she ate with him for the first time. The couple were then addressed by an aged man (*no-inmikokemit*) on the duties of marriage.

Finally, a number of old women accompanied the newly made wife to her husband's wigwam, carrying with them her bed-clothes. This final ceremony was called *natboonan*, taking or carrying the bed.

The End.

THE ETHNIC AFFINITIES OF THE GUETARES OF COSTA RICA.

BY DANIEL G. BRINTON, M.D.

(Read December 3, 1897.)

The Guetares, or Huetares, of Costa Rica, included various tribes speaking related dialects now believed to be wholly extinct. They dwelt on the lofty plateau of the interior, in the vicinity of Cartago and San José de Costa Rica, and for that reason received their name from their Nahuatl neighbors, which is a corruption of the Nahuatl *uei tlalli*, great land (Peralta).

They were a people of no mean culture, as the fine examples of worked gold ornaments and deftly carved stones obtained from their sepulchres and exhibited at the Madrid and Chicago exhibitions testify. Many of the best specimens now in the Museum of Costa Rica were collected from these interments by the director, Señor Anastasio Alfaro.

These remains justify the description of Juan Vasquez de Coronado, who was among them in 1562. He depicts them as of active intelligence, war-like in disposition, tall and well built, wearing cotton clothes skillfully woven, and having in their possession much gold. From other sources we learn that they were celebrated among the surrounding nations for their *mitotes*, sacred songs and dances; and that they were accustomed to make human sacrifices at the burial of important individuals.[1]

But where the Guetares belonged in the linguistic classification of American tribes has up to the present been an unsolved problem.

Writing in 1890, M. Alphonse Pinart asks: "In Costa Rica, those tribes called Guetares, who dwelt at first on the southern declivity of the Sierra and were driven thence by the invading Nahuas, were they not related to the Carib family of the southern continent?"[2] And in 1893, Manuel de Peralta, in his excellent study of Costa Rican ethnography, observes, "It is almost impossible to ascertain the ethnic affinities of the Guetares, since no vocabulary of their language has been found; but archæology shows that if they

[1] See M. de Peralta, *Costa Rica, Nicaragua y Panama en el Siglo xvi*, pp. 762, 770 (Madrid, 1883).

[2] Pinart, *Limite des Civilizations dans l'Isthme Americain* (Paris, 1890).

were not actually related to the Nahuas, they were at least under their cultural influence."[1]

These two guesses, so widely asunder, by eminent living authorities, indicate how uncertain ethnographers are as to the relationship of this once important and cultured people.

This uncertainty I shall endeavor to dispel by an examination of a few words preserved by early writers supposed to be in the Guetar language; by a comparison of some proper names stated to be from their tongue; and by the aid of an unpublished vocabulary obtained from what was believed to be the last remnant of the tribes, about forty years ago.

The traveler Benzoni visited the area of Costa Rica in 1528, and gives the following five words of the language of the "Suerra" (to be pronounced according to the Italian alphabet):[2]

Earth, *ischa*.

Men, *cici*.

Sickness, *stasa*.

Gold, *chiaruela*.

Great, *matto*.

A wild animal, *cascuii*.

These words mostly belong without doubt to the Talamancan linguistic substock. Thus, *ischia* = Talamanca *ischiko*, earth, and Cabecar *hizhku*. The word for men, *cici*, is the Cabecar, *jiji*; that for gold, *chiaruela*, appears a modification of the Talamanca *txela*, copper, perhaps yellow metal. The word for large, *matto*, belongs probably to the Cuna, which has *tumati*; and *cascuii* has too vague a meaning to identity. The term *stasa* for sickness does not appear in modern vocabularies.

But the "Suerre," although assumed by Dr. Berendt and others as identical with the Guetar tongue, is not positively known to be so; and geographically it appears to have been on the north coast along the river of the same name, some distance from the province of the historical Guetares.

I have found but one word of the ancient Guetar language preserved by the early conquistadores, but it is almost convincing of their linguistic position. This is *ueritecas* or *biritecas*, applied by them to the women of the neighboring province of Coto, because they went forth to battle with the men and joined like them in

[1] Translated in my *Report upon the collections exhibited at the Columbian Historical Exposition, Madrid*, p. 40, *sq.* (Washington, 1895).

[2] Benzoni, *Historia del Mondo Nuovo*, fol. 77 (Venice, 1572).

the fray.[1] This is clearly in the Talamancan tongue compounded of *era* or *wa-re*, woman, and probably *ituk*, to shoot, chop or strike.[2]

To this evidence may be added that of some geographical names. It is considered by local antiquaries that the names of several mountains in the region referred to belong to the extinct Guetar dialect. Examples of these are Excasu, Atarazu and Irazu. Here the termination *zu* cannot be else than the Cabecar *tsu* (Gabb), meaning hill or mountain.

Finally, I have a vocabulary taken at least forty years ago from some natives surviving near San José de Costa Rica, in the ancient Guetar territory. It is called Talamanca, but Mr. Gabb, who saw it, pronounced it to be of a different dialect; and Dr. Berendt, from whose collection it came, marked it as "antigua Talamanca." I believe it to be the only specimen of the Guetar dialect known, and as such I quote from it the list of words I used in my *American Race*, adding their similars in some other dialects of the stock.

VOCABULARY OF "ANCIENT TALAMANCA" OR GUETAR.

Man,	*pejelilli*	(Cabecar,	*pejettillé* = vir).
Woman,	*palacrak*	(*id.*,	*palacrak*).
Sun,	*cagune*	(*id.*,	*cagune*).
Moon,	*furia*	(*id.*,	*tura*).
Fire,	*yocó*	(*id.*,	*yocó*).
Water,	*dicre*	(*id.*,	*dicre*).
Head,	*sotacii*	(*id.*,	*sotacu*).
Eye,	*seguebra*	(*id.*,	*seguebra*, or *wobra*, Gabb).
Ear,	*secuque*	(*zgo-ku*,	Gabb).
Mouth,	*sequeque*	(*ko-kwu*,	*id.*).
Nose,	*seyiquete*	(*jïk*,	*id.*).
Tongue,	*seguecte*	(*kok-tu*,	*id.*).
Tooth,	*saka*	(*ka*,	*id.*).
Hand,	*seyura*	(*ura*,	*id.*).
Foot,	*ecuru*	(*kru-kwe*,	*id.*).
House,	*tu*	(*hu*,	*id.*).

This comparison leaves no room for doubt that this modern dialect, supposed to represent the ancient Guetar, is Talamancan, and closely allied to the Cabecar still spoken in Costa Rica; and from all the evidence above brought forward, the identification of the Guetares as a branch of the Talamancan linguistic group is sufficiently conclusive.

[1] Juan Vazquez de Coronado, in Peralta, U. S., p. 775.

[2] Gabb, *Indian Tribes and Languages of Costa Rica*, p. 533.

Stated Meeting, December 17, 1897.

Vice-President PEPPER in the Chair.

Present, 35 members.

Messrs. James S. deBenneville and Charles R. Hildeburn, newly elected members, were presented to the Chair and took their seats in the Society.

Acknowledgments of election to membership were received from Hon. Thomas F. Bayard and Prof. Frank Morley.

The Finance Committee presented a report and recommended the appropriations for the year, which were approved and ordered.

Prof. Morris Jastrow, Jr., made a communication on "The Original Character of the Jewish Sabbath."

Pending nominations were read and spoken to, and the Society proceeded to the election of new members, after which the Tellers reported that the following persons had been elected members :

2352. T. J. J. See, A.M., Ph.D. (Berlin), Flagstaff, Ariz.
2353. Sydney George Fisher, Philadelphia.
2354. Hon. Richard Olney, Boston.
2355. Edward S. Holden, Lick Observatory, Cal.
2356. Benjamin Kendall Emerson, Amherst.
2357. Rev. Francis L. Patton, D.D., LL.D., Princeton.
2358. Alden Sampson, Haverford, Pa.
2359. Ethelbert D. Warfield, Easton.
2360. Charles De Garmo, Swarthmore.
2361. William H. Dale, Washington.
2362. Arnold E. Ortmann, Ph.D., Princeton.
2363. Leroy W. McCay, D.Sc., Princeton.
2364. Henry B. Fine, Ph.D., Princeton.
2365. John B. Hatcher, Ph.D., Princeton.
2366. Charles F. W. McClure, M.A., Princeton.

The Society was adjourned by the presiding officer.

INDEX TO VOLUME XXXVI.

LIST OF MEMBERS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY.

FEBRUARY 12, 1898.

A

	Name.	Date of Election.	Present Address.
1687.	Abbe, Cleveland, Professor . .	July 27, 1871,	U. S. Weather Bureau, Washington, D. C.
2170.	Abbot, Dr. Charles Conrad . .	Dec. 20, 1889,	Trenton, N. J.
1463.	Abbot, Gen. Henry L.	April 18, 1862,	23 Berkeley Street, Cambridge, Mass.
2311.	Abbott, Alexander C., M.D. . .	Feb'y 19, 1897,	221 S. 44th Street, Philadelphia.
1809.	Åckerman, Richard, Professor.	July 21, 1876,	Stockholm, Sweden.
1713.	Acland, Sir Henry, Bart. . . .	Jan'y 17, 1873,	Oxford, England.
2128.	Adam, Lucien.	Dec. 17, 1886,	41 Bard Sevigné, Rennes, France.
2081.	Adams, Herbert B., Professor. .	May 21, 1886,	Baltimore, Md.
1779.	Agassiz, Alexander, Professor .	April 16, 1875,	Cambridge, Mass.
1642.	Agassiz, Mrs. Elizabeth	Oct. 15, 1869,	Quincy St., Cambridge, Mass.
1860.	Alison, Dr. Robert Henry. . .	May 3, 1878,	Ardmore, Montgomery Co., Pa
1869.	Allen, Joel Asaph	Sept. 20, 1878,	Am. Mus. Natural History, 77th St. and 8th Ave., New York.
1927.	Ames, Rev. Charles G.	Jan'y 21, 1881,	12 Chestnut St., Boston, Mass.
2064.	Anderson, George B., Lieut. .	Feb'y 19, 1886,	West Point, N. Y.
2164.	Angell, James B., Pres't.	Oct. 18, 1889,	Ann Arbor, Mich.
2224.	Appleton, William Hyde, Prof.	May 19, 1893,	Swarthmore, Pa.
2102.	Argyll, Duke of.	May 21, 1886,	London, England.
1761.	Armstrong, The Right Hon. Lord	July 17, 1874,	Cragside, Rothbury, England.
1996.	Ashhurst, John, Jr., M.D. . . .	Jan'y 18, 1884,	2000 Delancey Pl., Phila.
2012.	Ashhurst, Richard L.	April 18, 1884,	2204 Walnut St., Philadelphia.

B

	Name.	*Date of Election.*	*Present Address.*
1995.	Bache, R. Meade	Jan'y 18, 1884,	4400 Sansom St., Philadelphia.
1832.	Bache, Dr. Thomas Hewson	Feb'y 2, 1877,	233 S. 13th St., Philadelphia.
2285.	Bailey, L. H., Professor	May 15, 1896,	Cornell Univ., Ithaca, N. Y.
1630.	Baird, Henry Carey	Jan'y 15, 1869,	810 Walnut St., Philadelphia.
1991.	Baird, Henry M., Professor	Jan'y 18, 1884,	219 Palisade Ave., Yonkers, N. Y.
2345.	Baldwin, James Mark, Prof.	Oct. 15, 1897,	Princeton, N. J.
2191.	Ball, Sir Robert Stawell	May 15, 1891,	Observatory, Cambridge, Eng.
1965.	deBar, Hon. Edouard Sêve	July 21, 1882,	Ramsgate, England.
1818.	Barcena, Don Mariano, Prof.	Feb'y 2, 1877,	Museo Nacional, Mexico.
1741.	Barker, George F., Professor	April 18, 1873,	3909 Locust St., Philadelphia.
2011.	Barker, Wharton	April 18, 1884,	119 S. 4th St., Philadelphia.
1902.	Bartholow, Roberts, M.D.	April 16, 1880,	1525 Locust St., Philadelphia.
2119.	Bastian, Adolph, Professor	Dec. 17, 1886,	S. W. Königgrätzerstrasse 120, Berlin, Germany.
2337.	Bayard, Hon. Thomas F.	Oct. 15, 1897,	Wilmington, Del.
1934.	Beaulieu, M. Paul Leroy, Prof.	April 15, 1881,	No. 27 Ave. du Bois de Boulogne, Paris, France.
1968.	Bell, Alexander Graham, Prof.	July 21, 1882,	1336 19th St., Washington, D.C.
1802.	Bell, Sir Lowthian	April 21, 1876,	Northallerton, England.
2255.	Bement, Clarence S.	May 17, 1895,	1804 Spring Garden St., Phila.
2326.	deBenneville, James S	Oct. 15, 1897,	123 S. 7th Street, Philadelphia.
2264.	Berthelot, M. P. E. Marcelin	May 17, 1895,	Paris, France.
2253.	Bertin, Georges	May 17, 1895,	11 bis Rue Ballu, Paris.
2228.	Bessemer, Sir Henry	Feb'y 16, 1894,	Surrey, England.
2149.	Biddle, Alexander	Feb'y 17, 1888,	1307 Walnut St., Philadelphia.
1920.	Biddle, Cadwalader	Oct. 15, 1880,	1420 Walnut St., Philadelphia.
1831.	Biddle, Hon. Craig	Feb'y 2, 1877,	2033 Pine Street, Philadelphia.
2134.	Billings, John S., M.D.	Feb'y 18, 1887,	40 Lafayette Place, New York.
2256.	Bispham, George Tucker	May 17, 1895,	1805 Delancey Place, Phila.
2157.	Blair, Andrew A.	May 17, 1889,	406 Locust Street, Philadelphia.
1554.	Blair, Thomas S.	Jan'y 19, 1866,	P. O. Box 508, Tyrone, Pa.
1669.	Blake, Wm. Phipps, Professor	Oct. 21, 1870,	New Haven, Conn.
1700.	Blodget, Lorin	April 19, 1872,	1329 S. Broad St., Philadelphia.
1444.	Böhtlingk, M. Otto	Jan'y 17, 1862,	Seeburgstrasse 35, II, Leipzig.
2235.	Bonaparte, Prince Roland	Feb'y 15, 1895,	10 Ave. d' Jena 22, Paris.
2047.	Bonwill, W. G. A., D.D.S.	Oct. 16, 1885,	2009 Chestnut St., Philadelphia.
1126.	Boyè, Martin H., Professor	Jan'y 17, 1840,	Coopersburg, Lehigh Co., Pa.
1826.	Brackett, Cyrus Fogg, Professor	Feb'y 2, 1877,	Princeton, N. J.
2083.	Branner, John C., Professor	May 21, 1886,	Stanford Univ., Palo Alto, Cal.
2195.	Brezina, Dr. Aristides	May 21, 1886,	VII Siebensterngasse, 46, Vienna, Austria.
1636.	Brinton, Daniel G., M.D.	April 16, 1869,	Media, Delaware Co., Pa.
2069.	Brinton, John H., M.D	Feb'y 19, 1886,	1423 Spruce St., Philadelphia.
1745.	Brinton, J. Blodget	Oct. 17, 1873,	339 Walnut St., Philadelphia.
2080.	Brooks, William Keith, Prof.	May 21, 1886,	Johns Hopkins Univ., Baltimore, Md.
1881.	Brown, Arthur Erwin	April 18, 1879,	1208 Locust St., Philadelphia.
2275.	Brubaker, Albert P., M.D.	Oct. 18, 1895,	105 N. 34th St., Philadelphia.
1547.	Brush, George J., Professor	Jan'y 20, 1865,	Yale University, New Haven, Conn.
2236.	Budge, Dr. A. Wallis	Feb'y 15, 1895,	British Museum, London, Eng.
1653.	Bullock, Charles	Oct. 15, 1869,	1017 Clinton St., Philadelphia.
1452.	Bunsen, Robert W., Professor	Jan'y 17, 1862,	Heidelberg, Germany.
2007.	Burk, Rev. Jesse Y	Jan'y 18, 1884,	400 Chestnut St., Philadelphia.

C

Name.	Date of Election.	Present Address.
1938. Butler, Hon. William	April 15, 1881,	West Chester, Pa.
1788. Campbell, John Lyle, Prof. . .	July 16, 1875,	Crawfordsville, Ind.
1606. Canby, William Marriott . . .	Oct. 16, 1868,	1101 Delaware Avenue, Wilmington, Del.
2051. Cannizzaro, Tomaso	Oct. 16, 1885,	Santa Maria fuori cinta, Casa Roffa, Messina, Sicily.
1731. Capellini, Giovanni, Senator .	April 18, 1873,	Portovenere près Spezia, Italy.
1796. Carll, John F., Professor	Oct. 15, 1875,	Pleasantville, Venango Co., Pa.
1911. Carson, Hampton L.	April 16, 1880,	1033 Spruce St., Phila.
2260. Carter, Hon. James C	May 17, 1895,	54 Wall Street, New York City.
1707. Cassatt, Alexander J	Oct. 18, 1872,	Haverford, Del. Co., Pa.
2147. Castner, Samuel, Jr.	Dec. 16, 1887,	3729 Chestnut St., Philadelphia.
2152. Cattell, Dr. J. McKeen	May 18, 1888,	Garrison-on-Hudson, N. Y.
1908. Chance, Dr. Henry Martyn. .	April 16, 1880,	5164 Columbia Ave., Phila.
1783. Chandler, C. F., Professor .	April 16, 1875,	49th St., cor. 4th Av., N.Y. City.
1778. Chapman, Henry C., M.D. . . .	April 16, 1875,	2047 Walnut St., Philadelphia.
2132. de Charencey, Comte Hyacinth	Dec. 17, 1886,	25 rue Barbet de Jouy, Paris.
2158. Clark, Clarence H.	May 17, 1889,	42d and Locust Sts., Phila.
1717. Clarke, Thomas C. E	Jan'y 17, 1873,	44 Broadway, New York, N. Y.
1983. Claypole, E. W., Professor . . .	Jan'y 19, 1883,	Buchtell College, Akron, O.
2247. Cleeman, Richard A., M.D.. . .	Feb'y 15, 1895,	2135 Spruce St., Philadelphia.
2336. Cleveland, Hon. Grover, . . .	Oct. 15, 1897,	Westland, Princeton, N. J.
1999. Cohen, J. Solis, M.D.	Jan'y 18. 1884,	1341 Walnut St., Philadelphia.
2305. Conklin, Edwin Grant, Prof. .	Feb'y 19, 1897,	University of Penna., Phila.
2257. Cook, Joel	May 17, 1895,	849 N. Broad St., Philadelphia.
2129. Cora, Guido, Professor	Dec. 17, 1886,	Corso Vittorio Emanuele, 74, Turin, Italy.
1867. Coues, Elliott, M.D., U. S. A. .	Sept. 20, 1878,	Washington, D. C.
1662. Cox, Hon. Jacob D.	April 15, 1870,	Cincinnati, O.
2207. Cramp, Charles H	Dec. 16, 1892,	507 S. Broad St., Philadelphia.
1836. Crane, Thomas Frederick, Prof.	Feb'y 2, 1877,	Cornell Univ., Ithaca, N. Y.
2317. Culin, Stewart	May 21, 1897,	University of Penna , Phila.
2100. Crookes, William, Professor . .	May 21, 1886,	7 Kensington Park Gardens, London, W. England.
2172. Cruz, Hon. Fernando, M.D. . .	Dec. 20, 1889,	Washington, D. C.
1439. Curwen, John, M.D.	April 18, 1861,	Warren, Pa.
2296. Cushing, Frank H.	May 15, 1896,	Bureau of Ethnology, Washington, D. C.

D

Name.	Date of Election.	Present Address.
1567. Da Costa, J. M., M.D	Oct. 19, 1866,	1700 Walnut St., Philadelphia.
2361. Dall, William H.	Dec. 17, 1897,	U. S. National Museum Washington, D. C.
2214. Daly, Hon. Charles P.	May 19, 1893,	11 W. 29th St., New York, N. Y.
2282. Dana, Edw. S., Professor	May 15, 1896,	Yale Univ., New Haven, Conn.
1806. Dannefeld, C. Juhlin	April 21, 1876,	27 Gt. Winchester St., London.
1811. Davenport, Samuel.	Oct. 20, 1876,	Adelaide, S. Australia.
1557. Davidson, George.	Jan'y 19, 1866,	Observatory, San Francisco, Cal.
1923. Dawkins, Wm. Boyd, Prof. . . .	Oct. 15, 1880,	Woodhurst, Fallowfield, Manchester, England.
2360. De Garmo, Charles, President.	Dec. 17, 1897,	Swarthmore, Pa.
2208. Dercum, Francis X., M.D. .	Dec. 16, 1892,	1719 Walnut St., Philadelphia.
2013. Dickson, Samuel	April 18, 1884,	901 Clinton St., Philadelphia.

Name.	*Date of Election.*	*Present Address.*
2208. DIXON, SAMUEL G., M.D	Dec. 16, 1892,	Academy of Natural Sciences, Philadelphia.
2108. DOLLEY, CHARLES S., M.D. . . .	Dec. 17, 1886,	3707 Woodland Ave., Phila.
2089. DONNER, DR. OTTO.	May 21, 1886,	Helsingfors, Finland.
1946. DOOLITTLE, C. L., Professor . . .	Oct. 21, 1881,	College Hall, Univ. of Penna.
1839. DOUGLAS, JAMES	April 20, 1877,	Spuytenduyvil, NewYork, N.Y.
1924. DRAPER, DANIEL.	Oct. 15, 1880,	Meteorological Observ.,Central Park, New York, N. Y.
2303. DREER, FERDINAND J.	Feb'y 19, 1897,	1520 Spruce St., Philadelphia.
1787. DROWN, THOMAS M., President .	July 16, 1875,	Lehigh Univ.,S. Bethlehem, Pa.
1918. DU BOIS, PATTERSON	Oct. 15, 1880,	1031 Walnut St., Philadelphia.
1878. DUDLEY, CHARLES BENJAMIN . .	Jan'y 17, 1879,	Altoona, Blair Co., Pa.
2063. DUNCAN, LOUIS, U. S. N	Feb'y 19, 1886,	Johns Hopkins Univ.,Balt.,Md.
1573. DUNNING, GEORGE F.	Jan'y 18, 1867,	Farmington, Conn.
1727. DUPONT, EDOUARD	April 18, 1873,	Musée Royal Museum, Bruxelles, Belgium.
2227. DUPONT, COL. HENRY A	Feb'y 16, 1894,	Winterthur, Montchanen, Del.
1679. DUTTON,CLARENCE E.,Lieut.U.S.A	Jan'y 20, 1871,	U. S. Arsenal, Washington,D.C.

E

2105. EASTON, MORTON W., Professor .	Dec. 17, 1886,	224 S. 43d St., Philadelphia.
2271. EBERS, DR. GEORGE	May 17, 1895,	Tutzing, near Munich, Bavaria.
1917. ECKFELDT, JACOB B	Oct. 15, 1880,	U. S. Mint, Philadelphia.
1825. EDDY, H. TURNER, Professor. . .	Feb'y 2, 1877,	Univ. Minn., Minneapolis.
2294. EDISON, THOMAS A.	May 15, 1896,	Orange, N. J.
2262. EDMUNDS, HON. GEORGE F . . .	May 17, 1895,	1724 Spruce St., Philadelphia.
1686. ELIOT, DR. CHARLES W.	April 21, 1871,	17 Quincy St.,Cambridge,Mass.
2272. ELLIOTT, A. MARSHALL, Professor	May 17, 1895,	Baltimore, Md.
2313. ELY, THEODORE N.	May 21, 1897,	Broad St. Station, Phila.
2356. EMERSON, BENJ. KENDALL, Prof.	Dec. 17, 1897,	Amherst, Mass.
1981. EMMONS, S. F.	Jan'y 19, 1883,	U. S. Geological Survey, Washington, D. C.
1943. EVANS, SIR JOHN, K.C.B.	Oct. 21, 1881,	Nash Mills, Hemel Hempstead, England.
2254. EWELL, MARSHALL D., M.D . . .	May 17, 1895,	59 Clark St., Chicago, Ill.

F

2234. FENNELL, C. A. M., Litt.D. . . .	Feb'y] 15, 1895,	Cambridge, England.
2180. FIELD, ROBERT PATTERSON . . .	May 16, 1890,	218 S. 42d St., Philadelphia.
2364. FINE, HENRY B., Professor . . .	Dec. 17, 1897,	Princeton, N. J.
2353. FISHER, SYDNEY GEORGE	Dec. 17, 1897,	328 Chestnut St., Philadelphia.
1901. FLINT, AUSTIN, JR., M.D.	April 16, 1880,	14 W. 33d St., New York, N. Y.
1621. FLOWER, WM. HENRY, M.D. . . .	Jan'y 15, 1869,	South Kensington Museum, London, England.
1875. FOGGO, EDWARD A., D.D.	Oct. 18, 1878,	3216 Summer St., Philadelphia.
2197. FORBES, GEORGE, Professor. . . .	Oct. 16, 1891,	34 Great George St., London, England.
1170. FRALEY, HON. FREDERICK . . .	July 15, 1842,	2017 Delancey Place, Phila.
1912. FRALEY, JOSEPH C.	April 16, 1880,	714 Walnut St., Philadelphia.
2270. FRANKS, SIR AUGUSTUS W. . . .	May 17, 1895,	123 Victoria St., S. W. London, England.
1695. FRAZER, PERSIFOR, Dr. ès-Sc. Nat.	Jan'y 19, 1872,	928 Spruce St., Philadelphia.
301. FRAZIER, BENJ. W., Professor . .	Dec. 18, 1896,	Lehigh Univ., Bethlehem, Pa.

Name.	Date of Election.	Present Address.
2171. FRIEBIS, GEORGE, M.D.	Dec. 20, 1889,	1906 Chestnut St., Philadelphia.
2179. FULLERTON, GEORGE S., Rev. . .	May 16, 1890,	309 S. 40th St., W. Philadelphia.
1739. FULTON, JOHN	April 18, 1873,	136 Park Pl., Johnstown, Pa.
1914. FURNESS, HORACE H.	April 16, 1880,	Wallingford, Delaware Co., Pa.
2306. FURNESS, HORACE HOWARD, JR..	Feb'y 19, 1897,	2034 Delancey Place, Phila.
2304. FURNESS, WILLIAM H., 3d, M.D. .	Feb'y 19, 1897,	Wallingford, Del. Co., Pa.

G

Name.	Date of Election.	Present Address.
1988. GARRETT, PHILIP C	April 20, 1883,	Logan P. O., Philadelphia.
2079. GATES, MERRILL E., Dr	May 21, 1886,	Amherst, Mass.
1025. GATSCHET, ALBERT S., Dr	Oct. 17, 1884,	1330 F St., N. W., Wash'n, D. C.
1897. GEIKIE, SIR ARCHIBALD	Jan'y 16, 1880,	Geological Survey Office, 28 Jermyn St., London, England.
1803. GEIKIE, JAMES, Professor	April 21, 1876,	31 Merchiston Ave., Edinburgh. Scotland.
2067. GENTH, F. A., JR	Feb'y 19, 1886,	103 N. Front St., Philadelphia.
2274. GIBBS, J. WILLARD, Professor . .	May 17, 1895,	121 High St., New Haven, Conn.
1355. GIBBS, OLIVER WOLCOTT, Prof. .	July 21, 1854,	Newport, R. I.
1587. GILL, THEODORE N., M.D.	July 19, 1867,	Smithsonian Inst., Wash'n, D.C.
1800. GILMAN, DR. DANIEL C.	April 21, 1876,	25 N. Charles St., Baltimore, Md.
1950. GLADSTONE, RT. HON. WM. EWART	Oct. 21, 1881,	Hawarden, England.
2240. GLAISHER, JAMES W. L.	Feb'y 19, 1895,	The Shola, Heathfield Road, South Croydon, England.
2233. GLAZEBROOK, RICHARD T	Feb'y 15, 1895,	Cambridge, England.
2212. GOODALE, GEORGE LINCOLN, Prof.	Feb. 17, 1893,	Harv. Univ., Cambridge, Mass.
1680. GOODFELLOW, EDWARD	Jan'y 20, 1871,	1718 Corcoran St., Washington, D. C.
2292. GOODSPEED, ARTHUR W., Prof.	May 15, 1896,	Univ. of Pa. College Building, Philadelphia.
2203. GOODWIN, HAROLD.	May 20, 1892,	501 Walnut St., Philadelphia.
2232. GOODWIN, W. W., Professor . . .	Feb'y 15, 1895,	Cambridge, Mass.
1851. GRAY, ELISHA.	Jan'y 18, 1878,	220 Kinzie St., Chicago, Ill.
2222. GREEN, SAMUEL A., M.D.	Oct. 20, 1893,	Historical Soc., Boston, Mass.
1504. GREEN, WILLIAM HENRY, D.D . .	April 17, 1863,	Princeton, N. J.
1880. GREENE, WILLIAM H., M.D. . . .	April 18, 1879,	204 N. 36th St., Philadelphia.
2155. DE GREGORIO, MARCHESE ANTONIO	Dec. 21, 1888,	Al Molo, Palermo, Sicily.
2188. GREGORY, DR. CASPAR RÉNÉ. . .	May 15, 1891,	Naunhofstrasse 25, Marienhöhe, Leipzig-Stotteritz, Germany.
1815. GROTE, AUGUSTUS RADCLIFFE . .	Oct. 20, 1876,	Buffalo, N. Y.
2090. DE GUBERNATIS, ANGELO, Professor	May 21, 1886,	Florence, Italy.
1438. DE GUYANGOS, DON PASCUAL . .	April 19, 1861,	London, England.

H

Name.	Date of Election.	Present Address.
2054. HAECKEL, ERNST, Professor Dr. . .	Oct. 16, 1885,	Univ. Jena, Germany.
1658. HALE, REV. EDW. EVERETT . . .	Jan'y 21, 1870,	39 Highland St., Roxb'y, Mass.
1853. HALL, ASAPH, Professor	Jan'y 18, 1878,	U. S. Observ., Washington, D.C.
1795. HALL, CHARLES EDWARD.	Oct. 15, 1875,	Westport, Essex County, N. Y.
2219. HALL, ISAAC H., Professor	May 19, 1893,	Metropolitan Museum of Art, Central Park, New York, N.Y.
1356. HALL, JAMES, Prof.	July 21, 1854,	State Museum, Albany, N. Y.
2027. HALL, LYMAN B., Prof.	Jan'y 16, 1885,	161 N. 15th St., Philadelphia.
1412. HAMMOND, WILLIAM A., M.D. . .	Oct. 21, 1859,	Washington, D. C.

Name.	Date of Election.	Present Address.
2194. Hamy, Dr. E. T.	May 15, 1891,	40 Rue Lübeck, Ave. du Trocadero, Paris, France.
1337. Harding, George	Jan'y 20, 1851,	2036 Chestnut St., Phila.
2136. Harris, Joseph S.	May 20, 1887,	144 School Lane, Germantown, Philadelphia.
2246. Harrison, Chales C., Provost.	Feb'y 15, 1895,	1618 Locust St., Philadelphia.
1827. Hart, James Morgan, Professor.	Feb'y 2, 1877,	Cornell Univ., Ithaca, N. Y.
2365. Hatcher, John B., Professor . .	Dec. 17. 1897,	Princeton, N. J.
1764. von Hauer, Franz Ritter. .	Oct. 16, 1874,	Leoben, Austria.
1681. Haupt, Hermann, General . . .	April 21, 1871,	747 Portland Ave., St. Paul, Minnesota.
1862. Haupt, Lewis M., Professor . .	May 3, 1878,	107 N. 35th St., Philadelphia.
2082. Hayes, Richard Somers	May 21, 1886,	32 Nassau St., New York, N.Y.
2071. Hays, I. Minis, M.D.	Feb'y 19, 1886,	266 S. 21st St., Philadelphia.
1985. Heilprin, Angelo, Professor . .	April 20, 1883,	Acad. of Nat. Sciences, Phila.
2283. Henderson, C. H	May 15, 1896,	Philadelphia.
2218. Hewett, Waterman T., Prof . .	May 19, 1893,	Cornell Univ., Ithaca, N. Y.
2266. Heyse, Paul, Dr.	May 17, 1895,	Munich, Bavaria.
2349. Hildeburn, Charles R	Oct. 15, 1897,	1015 Clinton Street, Phila.
2307. Hiller, H. M., M.D.	Feb'y 19, 1897,	350 S. 16th Street, Phila.
2110. Hilprecht, Hermann V., Prof .	Dec. 17, 1886,	1031 Walnut St., Philadelphia.
1768. Himes, Charles Francis . .	Oct. 16, 1874,	Dickinson Coll., Carlisle Pa.
1663. Hitchcock, Chas. Henry, Prof.	April 15, 1870,	Dartmouth College, Hanover, N. H.
2160. Hoffman, Walter J., M.D . . .	Oct. 18, 1889,	U. S. Consulate, Manheim, Germany.
2355 Holden, Edward S.	Dec. 17, 1897,	Smithsonian Institution, Washington, D. C.
2068. Holland, James W., M.D. . . .	Feb'y 19, 1886,	2006 Chestnut St., Philadelphia.
1624. Hooker, Sir Joseph D.	Jan'y 15, 1869,	The Camp, Sunningdale, Eng.
2224. Hoppin, J. M., Professor	Oct. 20, 1893,	New Haven, Conn.
2070. Horner, Inman.	Feb'y 19, 1886,	1811 Walnut St., Philadelphia.
1941. Hotchkiss, Jedediah.	Oct. 21, 1881,	346 E. Beverly St , Staunton, Va.
1696. Hough, George W., Professor . .	Jan'y 19, 1872,	N. W. Univ., Evanston, Ill.
1698. Houston, Edwin J., Professor. .	Jan'y 19, 1872,	1809 Spring Garden St., Phila.
2346. Howe, Henry M., Prof.	Oct. 15, 1897,	27 W. 73d St., New York.
2239. Huggins, William.	Feb'y 15, 1895,	90 Upper Tulse Hill, S. W. London, England.
1843. Humphrey, H. C.	July 20, 1877,	44 Broadway, New York, N.Y.
2248. Hunter, Richard S.	Feb'y 15, 1895,	1413 Locust St., Philadelphia.
2231. Hyatt, Alpheus, Professor. . .	Feb'y 15, 1895,	Cambridge, Mass.
1426. Hyrtl, Joseph, Professor. . . .	July 20, 1860,	k. k. Akad. d. Wissenschaften, Vienna, Austria.

I

1773. Ingham, Wm. Armstrong. . . .	April 16, 1875,	320 Walnut St., Philadelphia.
2221. d'Invilliers, Edward Vincent.	May 19, 1893,	711 Walnut St., Philadelphia.

J

2010. James, Edmund J., Prof.	April 18, 1884,	Univ. of Chicago, Chicago, Ill.
1933. Jannet, Claudio	April 15, 1881,	11 Rue las Casas, Paris, France.
2302. Jastrow, Morris, Jr.	Feb. 19, 1897,	248 S. 23d St., Philadelphia.
2049. Jayne, Horace, M.D.	Oct. 16, 1885,	318 S. 19th St., Philadelphia.

Name.	*Date of Election.*	*Present Address.*
1954. Jefferis, William W	Jan'y 20, 1882,	1836 Green St., Philadelphia.
2017. Jordan, Francis, Jr.	April 18, 1884,	111 N. Front St., Philadelphia.

K

1989. Kane, Elisha Kent.	April 20, 1883,	Kane, Pa.
2322. Karpinski, Alex. Petrovitch .	May 21, 1897,	Geological Survey, St. Petersburg, Russia.
2169. Keane, John J., Right Rev. . .	Dec. 20, 1889,	Washington, D. C.
2329. Keen, Gregory B.	Oct. 15, 1897,	3237 Chestnut St., Philadelphia.
2021. Keen, William W., M.D., Prof.	July 18, 1884,	1729 Chestnut St., Philadelphia.
1723. Kelvin, Lord, (Sir Wm. Thomson).	April 18, 1873,	University of Glasgow, Glasgow, Scotland.
1161. Kendall, E. Otis, Professor . .	Jan'y 21, 1842,	"The Stratford," Philadelphia.
2278. Kennelly, A. E., D.Sc	Feb. 28, 1896,	1105 Betz Building, Phila.
2118. Kiepert, Henry, Professor Dr.	Dec. 17, 1886,	Berlin, Germany.
1708. King, Clarence.	Oct. 18, 1872,	18 Wall St., New York, N. Y.
1767. König, George A., Professor . .	Oct. 16, 1874,	Sch. of Mines, Houghton, Mich.
2167. Krauss, Friederich S., Dr. . .	Dec. 20, 1889,	VII Neustiftgasse 12, Vienna.

L

1694. Lambert, Guillaume, Professor.	Jan'y 19, 1872,	Univ. of Louvain, Belgium.
2344. Lanciani, Rudolfo	Oct. 15, 1897,	2 Via Goito, Rome, Italy.
1858. Landreth, Burnet.	Jan'y 18, 1878,	Bristol, Pa.
1781. Langley, Samuel P., Professor .	April 16, 1875,	Smithsonian Institution, Washington, D. C.
1721. La Roche, C. Percy, M.D. . . .	Jan'y 17, 1873,	1518 Pine Street, Philadelphia.
1974. Lawes, Sir John B.	Jan'y 19, 1883,	Rothamstead, Herts, England.
1595. Lea, Henry Charles.	Oct. 18, 1867,	2000 Walnut St., Philadelphia.
1737. Le Conte, Joseph, Professor . .	April 18, 1873,	Univ. of California, Berkeley, Cal.
2241. Legge, James, Rev	Feb. 15, 1895,	Oxford, England.
1986. Lehman, Ambrose E.	April 20, 1883,	711 Walnut St., Philadelphia.
2182. Leland, Charles G.	May 16, 1890,	Baring Bros. & Co., London, England.
2174. Le Moine, Hon. J. M.	Dec. 20, 1889,	Quebec, Canada.
2324. Leonard, James B.	Oct. 15, 1897,	1813 Spruce St., Philadelphia.
1382. Lesley, J. Peter, Professor. . .	July 13, 1856,	Milton, Mass.
2085. Levasseur, Emile, Professor . .	May 21, 1886,	26, Rue Mons le Prince, Paris.
1415. Lewis, Francis W., M.D.	Jan'y 20, 1860,	2016 Spruce St., Philadelphia.
2300. Lewis, G. Albert	Dec. 18, 1896,	1834 Delancey Place, Philadelphia.
2338. Libbey, William, Professor. . .	Oct. 15, 1897,	Princeton, N. J.
2312. Lister, The Right Hon. Lord .	May 21, 1897,	12 Park Crescent, Portland Place, London, Eng.
1756. Lockyer, Sir Joseph Norman, K. C. B	April 17, 1874,	Royal Col. of Sci., S. Kensington, London S. W., England.
1798. Longchamps, Baron de Selys .	April 18, 1873,	Liège, Belgium.
1872. Longstreth, Morris, M.D. . . .	Sept. 20, 1878,	1416 Spruce St., Philadelphia.
2202. Low, Hon. Seth	Feb. 19, 1892,	Columbia College, New York.
2350. Lowell, Percival.	Oct. 15, 1897,	Lowell Obs., Flagstaff, Arizona.
2019. Lubbock, Sir John	July 18, 1884,	15 Lombard St., London, Eng.
2003. Ludlow, William, Col. U. S. A.	Jan'y 18, 1884,	Army Building, 39 Whitehall St., New York.
1629. Lyman, Benjamin Smith	Jan'y 15, 1869,	708 Locust St., Philadelphia.

M

Name.	*Date of Election.*	*Present Address.*
2319. Mabery, Charles F., Prof. . . .	May 21, 1897,	Case School of Applied Science, Cleveland, O.
2107. MacAlister, James, Pres.	Dec. 17, 1886,	119 N. 18th St., Philadelphia.
2209. Macfarlane, John M., Prof. . .	Dec. 16, 1892,	Lansdowne, Delaware Co., Pa.
2334. MacVeagh, Wayne, Hon	Oct. 15, 1897,	Bryn Mawr, Pennsylvania.
2363. McCay, Leroy W., Prof.	Dec. 17, 1897,	Princeton, N. J.
2366. McClure, Charles F. W., Prof.	Dec. 17, 1897,	Princeton, N. J.
2280. McCook, Henry C., Rev., D.D. .	Feb. 28, 1896,	3700 Chestnut St., Philadelphia.
1888. McCreath, Andrew S.	July 18, 1879,	223 Market St., Harrisburg, Pa.
1821. McKean, William V.	Feb'y 2, 1877,	200 N. 19th St., Philadelphia.
2299. Magie, Wm. Francis, Prof. . . .	Dec. 19, 1896,	Princeton, N. J.
2339. Mahan, Alfred T., Capt. U. S. N.	Oct. 15, 1897,	160 W. 86th St., New York.
2042. Mallet, John Wm., M.D. . . .	Jan'y 16, 1885,	University of Virginia, Charlottesville, Va.
1847. Mansfield, Ira Franklin . . .	Jan'y 18, 1878,	Cannelton, Beaver Co., Pa.
1857. March, Francis Andrew, Prof.	Jan'y 18, 1878,	Lafayette College, Easton, Pa.
1861. Marks, William D., Professor .	May 3, 1878,	1014 Betz Bldg., Philadelphia.
1604. Marsh, Othniel C., Professor. . .	Oct. 16, 1868,	Yale University, New Haven, Conn.
2078. Marshall, John, M.D	May 21, 1886,	1409 Spruce St,, Philadelphia.
2184. Mascart, E., Professor	Dec. 19, 1890,	176 Rue de l'Université, Paris.
1572. Mason, Andrew, ...	Jan'y 18, 1867,	30 and 32 Wall St., New York.
2196. Maspero, Gaston, Professor . . .	May 15, 1891,	Paris, France.
2279. Mason, Wm. Pitts, M.D., Prof. .	Feb. 28, 1896,	Rensselaer Polytechnic Institute, Troy, N. Y.
1677. Meehan, Thomas	Jan'y 20, 1871,	Germantown, Philadelphia.
2115. von Meltzel, Hugo, Prof. Dr. .	Dec. 17, 1886,	Koloszvar, Hungary.
2339. Melville, George Wallace, Com. U. S. N..	Oct. 15, 1897,	Navy Dept., Washington, D. C.
2251. Mercer, Henry C.	Feb. 15, 1895,	Doylestown, Pa.
1903. Merrick, John Vaughan. . . .	April 16, 1880,	Roxborough, Philadelphia.
1947. Merriman, Mansfield, Prof. .	Oct. 21, 1881,	Lehigh Univ., Bethlehem, Pa.
1744. Messchert, Matthew Huizinga.	Oct. 17, 1873,	Douglassville, Berks Co., Pa.
2142. Michael, Mrs. Helen Abbott.	May 20, 1887,	44 Mt. Vernon St., Boston, Mass.
2284. Minot, Chas. Sedgwick, M.D. .	May 15, 1896,	Harvard Univ., Cambridge.
2175. Mitchell, Hon. James T. . . .	Feb'y 21, 1890,	1722 Walnut St., Philadelphia.
1461. Mitchell, S. Weir, M.D	Jan'y 17, 1862,	1524 Walnut St., Philadelphia.
2267. Montegazza, Paolo	May 17, 1895,	Florence, Italy.
2323. Moore, Clarence B.	Oct. 15, 1897,	1321 Locust Street, Phila.
2029. Moore, James W., M.D.	Jan'y 16, 1885,	Lafayette College, Easton, Pa.
1841. Morehouse, George R., M.D. .	April 20, 1877,	2033 Walnut St., Philadelphia.
2340. Morley, Frank, Professor . . .	Oct. 15, 1897,	Haverford, Pa.
1976. Morris, J. Cheston, M.D.	Jan'y 19, 1883,	1514 Spruce St., Philadelphia.
2265. Morse, Edward S., Professor . .	May 17, 1895,	Essex Institute, Salem, Mass.
2242. de Mortillet, Gabriel . . .	Feb. 15, 1895,	St. Germain-en-Laye, France.
1577. Morton, Henry, President . . .	Jan'y 18, 1867,	Hoboken, N. J.
2121. Much, Dr. Matthæus.	Dec. 17, 1886,	XIII Penzingerstrasse 84, Vienna.
2120. Mueller, Dr. Friederich . . .	Dec. 17, 1886.	XIII Marxergasse 24, Vienna.
1486. Mueller, F. Max, Professor . .	Jan'y 16, 1863,	Univ. Oxford, England.
1866. Muhlenberg, Rev. Fred A. . .	Sept. 20, 1878,	34 S. 5th St., Reading, Pa.
2192. Munroe, Charles E., Professor.	May 15, 1891,	Columbian Univ. Washington, D. C.
2062. Murdock, J. B., Lieut. U.S.N . .	Feb'y 19, 1886,	Navy Dept., Washington, D.C.

N

	Name.	Date of Election	Present Address.
1937.	MURRAY, JAMES A. H., Dr . . .	April 15, 1881,	Oxford, England.
2087.	DE NADAILLAC, MARQUIS.	May 21, 1886,	18 Rue Duphot, Paris, France.
2316.	NANSEN, FRIDTJOF	May 21, 1897,	Lysaker, Norway.
1852.	NEWCOMB, SIMON, Professor . . .	Jan'y 18, 1878,	U. S. Nautical Almanac Office, Washington, D. C.
1703.	NICHOLS, STARR HOYT	July 19, 1872,	64 Exchange Pl., New York, N.Y.
2060.	NIKITIN, SERGE, Chief Geolog .	Feb'y 19, 1866,	Geological Survey, St. Petersburg, Russia.
1805.	NORDENSKIÖLD, ADOLF ERIC, Prof.	April 21, 1876,	Stockholm, Sweden.
1712.	NORRIS, ISAAC, M.D.	Oct. 18, 1872,	2043 Walnut St., Philadelphia.
2106.	NORRIS, WILLIAM F., M.D. . . .	Dec. 17, 1886,	1530 Locust St., Philadelphia.
2046.	NORTH, EDWARD, LL.D., Prof . .	Oct. 16, 1885,	Hamilton College, Clinton, N.Y.
2269.	NUTTALL, MRS. ZELIA	May 17, 1895,	Beuststrasse 17, Dresden.

O

2072.	OLIVER, CHARLES A., M.D. . . .	Feb'y 19, 1886,	1507 Locust St., Philadelphia.
2354.	OLNEY, RICHARD, Hon	Dec. 17, 1897,	23 Court Street, Boston.
2195.	OPPERT, JULIUS, Professor Dr . .	May 15, 1891,	Paris, France.
2362.	ORTMANN, ARNOLD E., Prof . . .	Dec. 17, 1897,	Princeton, N. J.
2320.	ORTON, EDWARD	May 21, 1897,	State University, Columbus, O.
2135.	OSBORN, HENRY F., Professor. .	Feb'y 18, 1887,	Amer. Museum of Natural History, New York City.
2039.	OSLER, WILLIAM, M.D	Jan'y 16, 1885,	1 West Franklin St., Baltimore, Md.

P

1868.	PACKARD, A. S., Dr	Sept. 20, 1878,	Providence, R. I.
1578.	PACKARD, JOHN H., M.D.	Jan'y 18, 1867,	Hotel Stenton, Philadelphia.
1331.	PAGET, SIR JAMES, Bart	Jan'y 20, 1854,	5 Park Square W., Regents Park, London, England.
2035.	PATTERSON, C. STUART.	Jan'y 16, 1885,	1000 Walnut St., Philadelphia.
1282.	PATTERSON, ROBERT	April 18, 1851,	329 Chestnut St., Philadelphia.
1320.	PATTERSON, THOMAS LEIPER . .	April 15, 1853,	176 Washington St., Cumberland, Md.
2213.	PATTISON, ROBERT E., Hon . . .	Feb. 17, 1893,	5930 Drexel Rd., Overbrook, Pa.
2357.	PATTON, FRANCIS L., D.D., Pres't	Dec. 17, 1897,	Princeton, N. J.
1772.	PEARSE, JOHN B.	Jan'y 15, 1875,	317 Walnut Av., Roxbury, Mass.
2318.	PECKHAM, S. F.	May 21, 1897,	Univ. Mich., Ann Arbor, Mich.
1859.	PEIRCE, C. NEWLIN, D.D.S. . . .	May 3, 1878,	1415 Walnut St., Philadelphia.
1722.	PEMBERTON, HENRY.	Jan'y 17, 1873,	1947 Locust St., Philadelphia.
2104.	PEÑAFIEL, ANTONIO, Dr.	May 21, 1886,	Ciudad, Mexico, Mexico.
2073.	PENNYPACKER, SAMUEL W., Hon.	May 21, 1886,	1540 N. 15th St., Philadelphia.
1518.	PENROSE, R. A. F., M.D.	July 17, 1863,	1331 Spruce St., Philadelphia.
2059.	PEPPER, EDWARD, M.D.	Feb'y 19, 1886,	El Afia, El Biar, Alger, Algerie.
2333.	PEPPER, GEORGE WHARTON . . .	Oct. 15, 1897,	701 Drexel Building, Phila.
1666.	PEPPER, WILLIAM, M.D.	July 15, 1870,	1811 Spruce St., Philadelphia.
2281.	PETTIT, HENRY	Feb. 28, 1895,	5951 Overbrook Ave., Phila.
2261.	PHELPS, EDWARD J., Hon. . . .	May 17, 1895,	Burlington, Vt.
2295.	PICKERING, EDW. C., Professor .	May 15, 1896,	Harvard Univ. Observatory, Cambridge, Mass.
2342.	PIERSOL, GEORGE A., M.D.	Oct. 15, 1897,	Chester Ave. and 49th St., Phila.
2277.	PILSBRY, HENRY A., Professor. .	Dec. 20, 1895,	Acad. Nat. Sci., Philadelphia.

Name.	Date of Election.	Present Address.
1760. PLATT, FRANKLIN	July 17, 1874,	1617 Chestnut St., Philadelphia.
2127. PLATZMANN, JULIUS, Dr.	Dec. 17, 1886,	Reichsstrasse 2, Leipzig.
2053. POMIALOWSKY, JOHN, Professor .	Oct. 16, 1885,	St. Petersburg, Russia.
1539. PORTER, THOMAS C., Rev.	Oct. 21, 1864,	Lafayette College, Easton, Pa.
2097. POSTGATE, J. P., Professor	May 21, 1886,	Cambridge, England.
2161. POWELL, J. W., MAJOR.	Oct. 18, 1889,	910 M. St., N. W., Washington, D. C.
1780. PRIME, FREDERICK.	April 16, 1875,	1008 Spruce St., Philadelphia.
2088. PULZSKY, FRANCIS, Dr	May 21, 1886,	Buda-Pesth, Hungary.
1758. PUMPELLY, RAPHAEL	April 17, 1874,	Newport, R. I.
2293. PUPIN, MICHAEL I., Professor . .	May 15, 1896,	7 Highland Pl., Yonkers, N. Y.
2268. PUTNAM, F. W., Prof.	May 15, 1895,	Harvard Univ., Cambridge, Mass.

R

Name.	Date of Election.	Present Address.
2131. RADA, JUAN DE DIOS-Y DELGADO,	Dec. 17, 1886,	Calle de la Corredera baja de S. Pablo No. 12, Madrid, Spain.
1736. RAND, THEODORE D	April 18, 1873,	Radnor, Del.Co., Pennsylvania.
1849. RANDALL, F. A., Dr	Jan'y 18, 1878,	Warren, Pa.
1644. RAWLINSON, GEORGE, Professor .	Oct. 15, 1869,	Oxford, England.
1765. RAWSON, SIR RAWSON W.	Oct. 16, 1874,	68 Cornwall Gardens, Queen's-gate, London S.W., England.
2099. RAYLEIGH, LORD.	May 21, 1886,	TerlingPl.,Witham,Essex,Eng.
1784. RAYMOND, ROSSITER W.	April 16, 1875,	13 Burling Slip, New York,N.Y.
1889. REMSEN, IRA, Professor.	July 18, 1879,	Johns Hopkins Univ. Baltimore, Md.
1948. RENARD, A. F., Professor	Oct. 21, 1881,	Acad. of Sci.,Brussels,Belgium.
1343. RENARD, CHARLES, M.D	Jan'y 20, 1854,	Moscow, Russia.
1890. RENEVIER, E., Professor.	July 18, 1879,	Univ. Lausanne, Switzerland.
1816. REULEAUX, F., Professor Dr . . .	Feb'y 2, 1877,	Ahornstrasse 2, Berlin.
2122. RÉVILLE, ALBERT, Professor Dr .	Dec. 17, 1886,	21 Rue Guénégaud, Paris.
2315. RHOADS, SAMUEL NEELY	May 21, 1897,	Acad. Nat. Sci., Philadelphia.
2226. ROBERTS, ISAAC, Dr.	Oct. 20, 1893,	Starfield,Crowborough,Sussex, England.
1957. ROBINS, JAMES W., Rev	April 21, 1882,	Merion Station, Montg. Co., Pa.
1390. ROGERS, FAIRMAN	Jan'y 16, 1857,	Univ. of Pa., Philadelphia.
2177. ROGERS, ROBERT W., Professor. .	Feb'y 21, 1890,	Drew Theological Seminary, Madison, N. J.
1462. ROHRIG, F. L. OTTO, Professor . .	April 18, 1862,	Los Angeles, Cal.
2050. ROLLETT, HERMANN, Dr.	Oct. 16, 1885,	Baden bei Wien, Austria.
1907. ROOD, OGDEN N., Professor. . . .	April 16, 1880,	Columbia College, New York City.
2198. ROSENGARTEN, JOSEPH G.	Oct. 16, 1891,	1704 Walnut St., Philadelphia.
1964. DE ROSNY, LÉON, Professor. . . .	July 21, 1882,	47 Ave. Duquêsne, Paris.
1838. ROTHROCK, JOSEPH T., Professor	April 20, 1877,	West Chester, Pa.
2291. ROWLAND, HENRY A., Professor .	May 15, 1896,	Johns Hopkins Univ., Baltimore, Md.
1620. RÜTIMEYER, DR. CARL L., Prof. .	Jan'y 15, 1869,	Basle, Switzerland.

S

Name.	Date of Election.	Present Address.
2230. SACHSE, JULIUS F.	Feb'y 16, 1894,	4428 Pine St., Philadelphia.
1766. SADTLER, SAMUEL P., Prof. . . .	Oct. 16, 1874,	1042 Drexel Building, Phila.
2148. SAJOUS, CHARLES E., M.D	Feb'y 17, 1888,	2043 Walnut St., Philadelphia.
2358. SAMPSON, ALDEN.	Dec. 17, 1897,	Haverford, Pa.

	Name.	*Date of Election.*	*Present Address.*
1563.	Sandberger, Fredolin, Prof.	April 20, 1866,	Univ. of Würtzburg, Bavaria.
2327.	Sanders, Richard H.	Oct. 15, 1897,	1225 Locust St., Philadelphia.
1958.	Sargent, Charles Sprague, Prof.	April 21, 1882,	Jamaica Plain, Mass.
1730.	Saussure, Henri de	April 18, 1873,	Geneva, Switzerland.
2211.	Schäffer, Charles, M.D.	Feb'y 17, 1893,	1309 Arch St., Philadelphia.
1498.	Schott, Charles Anthony, Prof.	April 17, 1863,	U. S. Coast and Geodetic Survey, Washington, D. C.
1864.	Schurz, Carl, Hon	Sept. 20, 1878,	54 William St., New York, N.Y.
1725.	Sclater, Phillip Lutley	April 18, 1873,	3 Hanover Square, London, England.
2112.	Scott, W. B., Prof.	Dec. 17, 1886,	Princeton, N. J.
1870.	Scudder, Samuel Hubbard	Sept. 20, 1878,	Cambridge, Mass.
2352.	See, T. J. J., Ph.D	Dec. 17, 1897,	Lowell Observatory, Flagstaff, Ariz.
1704.	Sellers, Coleman	July 19, 1872,	3301 Baring St., Philadelphia.
1533.	Sellers, William	April 15, 1864,	Clifton, Edgemoor, Delaware.
1770.	Selwyn, Alfred R. C., Dr.	Oct. 16, 1874,	28 Nepean St., Ottawa, Canada.
2057.	Sergi, Giuseppe, Prof.	Oct. 16, 1885,	Università Romana, Rome, Italy
2076.	Sharp, Benjamin, M.D.	May 21, 1886,	317 N. 35th St., Philadelphia.
1944.	Sharples, Philip Price	Oct. 21, 1881,	West Chester, Pennsylvania.
1960.	Sharples, Stephen Paschall	April 21, 1882,	13 Broad St., Boston, Mass.
1797.	Sherwood, Andrew	Oct. 15, 1875,	Mansfield, Tioga Co., Penna.
1822.	Shields, Chas. W., D.D.	Feb'y 2, 1877,	Princeton, N. J.
2351.	Smith, A. Donaldson, M.D	Oct. 15, 1897,	1811 Walnut St., Philadelphia.
2146.	Smith, Edgar F., Professor	Oct. 21, 1887,	210 S. 37th St., Philadelphia.
1789.	Smith, Stephen, M.D	Oct. 15, 1875,	57 W. 42d St., New York, N. Y.
2335.	Smock, John C.	Oct. 15, 1897,	Trenton, N. J.
2141.	Smyth, Albert H., Professor,	May 20, 1887,	Radnor, Delaware Co., Pa.
2229.	Snellen, Herman, Jr., Dr.	Feb'y 16, 1894,	Utrecht, Netherlands.
1724.	Snowden, A. Loudon	Oct. 17, 1873,	1812 Spruce St., Philadelphia.
2009.	Snyder, Monroe B., Professor	Jan'y 18, 1884,	2402 N. Broad St., Philadelphia.
1720.	Spofford, A. R.,	Jan'y 17, 1873,	Washington, D. C.
2332.	Squibb, Edward R., M.D	Oct. 15, 1897,	Brooklyn, N. Y.
1949.	Stallo, Hon. John B.	Oct. 21, 1881,	Cincinnati, O.
2348.	Stephens, H. Morse, Prof.	Oct. 15, 1897,	Cornell Univ., Ithaca, N. Y.
1990.	Stevens, Walter LeConte, Prof.	Jan'y 18, 1884,	Rensselaer Polytechnic Institute, Troy, N. Y.
1840.	Stevenson, John James, Prof.	April 20, 1877,	Univ. Heights, New York, N.Y.
2276.	Stevenson, Sara Y.	Oct. 18, 1895,	237 S. 21st St., Philadelphia.
2168.	Stokes, Sir George G.	Dec. 20, 1889,	Linfield Cottage, Cambridge, England.
2193.	Stubbs, William, Rt. Rev., D.D.	May 15, 1891,	Cleveden Palace, Oxford, Eng.
2094.	Suess, Edward, Professor	May 21, 1886,	Geol. Reichsanstalt, Vienna.
2258.	Sulzberger, Mayer, Hon.	May 17, 1895,	1303 Girard Ave., Philadelphia.
2092.	Szombathy, Josef, Professor	May 21, 1886,	Burgring 7, Vienna, Austria.

T

2328.	Tatham, William	Oct. 15, 1897,	1811 Walnut St., Philadelphia.
1786.	Tatham, William P.	April 16, 1875,	1420 Walnut St., Philadelphia.
2243.	Taylor, Isaac, D.D., Rev.	Feb'y 15, 1895,	York, England.
2098.	Temple, Richard Carnac, Lieut-Col.	May 21, 1886,	Government House, Port Blair, Andeman Islands, E. Indies.
2289.	Tesla, Nikola	May 15, 1896,	46 E. Houston St., New York City.

Name.	*Date of Election.*	*Present Address.*
2006. THOMAS, ALLEN C., Professor. .	Jan'y 18, 1884,	Haverford, Pa.
1993. THOMPSON, HEBER S.	Jan'y 18, 1884,	Pottsville, Pa.
1726. THOMPSON, SIR HENRY.	April 18, 1873,	35 Wimpole St., Cavendish Square, London, England.
1807. THOMSON, ELIHU, Professor . . .	April 21, 1876,	Swampscott, Mass.
1754. THOMSON, FRANK	April 17, 1874,	Merion, Penna.
1909. THOMSON, WILLIAM, M.D.	April 16, 1880,	1426 Walnut St., Philadelphia.
2052. IM THURN, EVERARD F.	Oct. 16, 1885,	Pomeroon River, Georgetown, British Guiana, S. A.
1530. THURY, A., Professor	April 15, 1864,	Univ. Geneva, Switzerland.
1688. TILGHMAN, BENJAMIN C., Gen . .	July 21, 1871,	1114 Girard St., Philadelphia.
1233. TILGHMAN, RICHARD A.	April 16, 1847,	321 S. 11th St., Philadelphia.
1657. TILGHMAN, WILLIAM M.	Jan'y 21, 1870,	1114 Girard St., Philadelphia.
2176. TIMMINS, SAMUEL	Feb. 21, 1890,	Arley, near Coventry, England.
2123. TOPINARD, DR. PAUL.	Dec. 17, 1886,	105 Rue de Rennes, Paris.
2065. TOPPAN, ROBERT NOXON.	Feb'y 19, 1886,	10 Highland St., Cambridge, Mass.
2249. TOWER, CHARLEMAGNE, JR., Hon.	Feb'y 15, 1895,	U.S. Embassy, Vienna, Austria.
2309. TRIMBLE, HENRY.	Feb. 19, 1897,	St. David's, Pennsylvania
2288. TROWBRIDGE, JOHN, Professor . .	May 15, 1896,	Harv. Univ., Cambridge, Mass.
2024. TRUMBULL, HENRY C., D.D., Rev.	July 18, 1884,	1031 Walnut St., Philadelphia.
2321. TSCHERNYSCHEW, THEODORE. . .	May 21, 1897,	Geological Survey, St. Petersburg, Russia.
1973. TSCHERMAK, GUSTAV, ...	Oct. 20, 1882,	Universität. Vienna, Austria.
1529. V. TUNNER, PETER R., Professor..	April 15, 1864,	Leoben, Austria.
1983. TURRETTINI, THEODORE, Prof . .	Dec. 19, 1890,	Geneva, Switzerland.
2166. TUTTLE, DAVID K	Oct. 18, 1889,	U. S. Mint, Philadelphia.
2163. TYLER, LYON G., Hon., President	Oct. 18, 1889,	Williamsburg, Va.
2138. TYSON, JAMES, M.D	May 20, 1887,	1506 Spruce St., Philadelphia.

U

2185. UNWIN, WILLIAM C., Professor. .	Dec. 19, 1890,	7 Palace Gate Mansions, London, England.

V

2325. VAUX, GEORGE, JR.	Oct. 15, 1897,	404 Girard Building, Phila.
2045. DE VERE, M. SCHELE, Professor .	Oct. 16, 1885,	University of Virginia, Charlottesville, Albemarle Co., Va.
1475. VIRCHOW, RUDOLPH, Prof. Dr . .	Oct. 17, 1862,	Universität, Berlin, Germany.
1670. VOSE, GEORGE L., Professor . . .	Oct. 21, 1870,	Massachusetts Institute of Technology, Boston.
2186. VOSSION, LOUIS	Dec. 19, 1890,	Consulate of France, Honolulu.

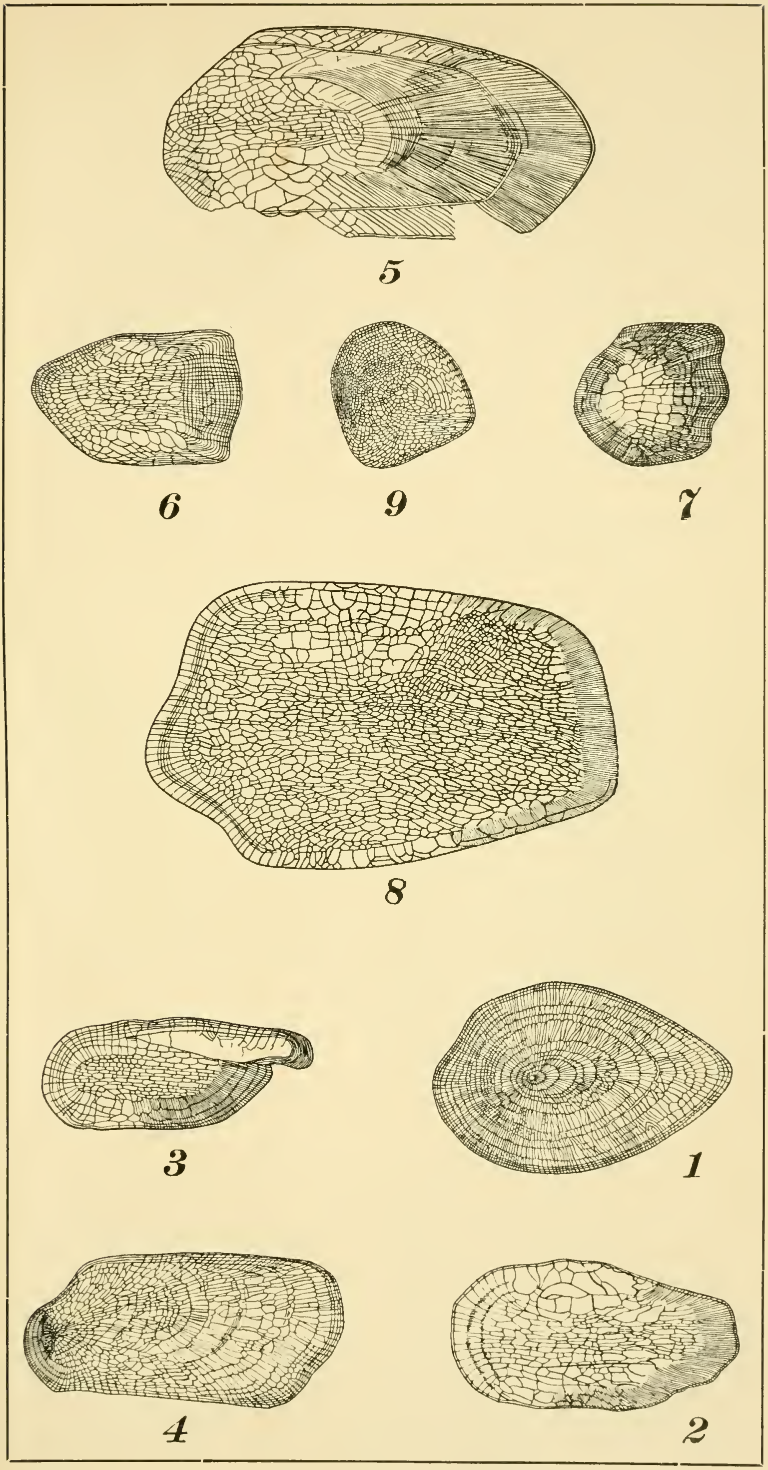
W

2034. WAGNER, SAMUEL	Jan'y 16, 1885,	133 S. 12th St., Philadelphia.
1748. WAHL, WILLIAM H.	Jan'y 16, 1874,	15 S. 7th St., Philadelphia.
2331. WALCOTT, CHARLES D., Director .	Oct. 15, 1897,	U. S. Geological Survey, Washington, D. C.
1724. WALLACE, ALFRED R.	April 18, 1873,	Parkstone, Dorset, England.

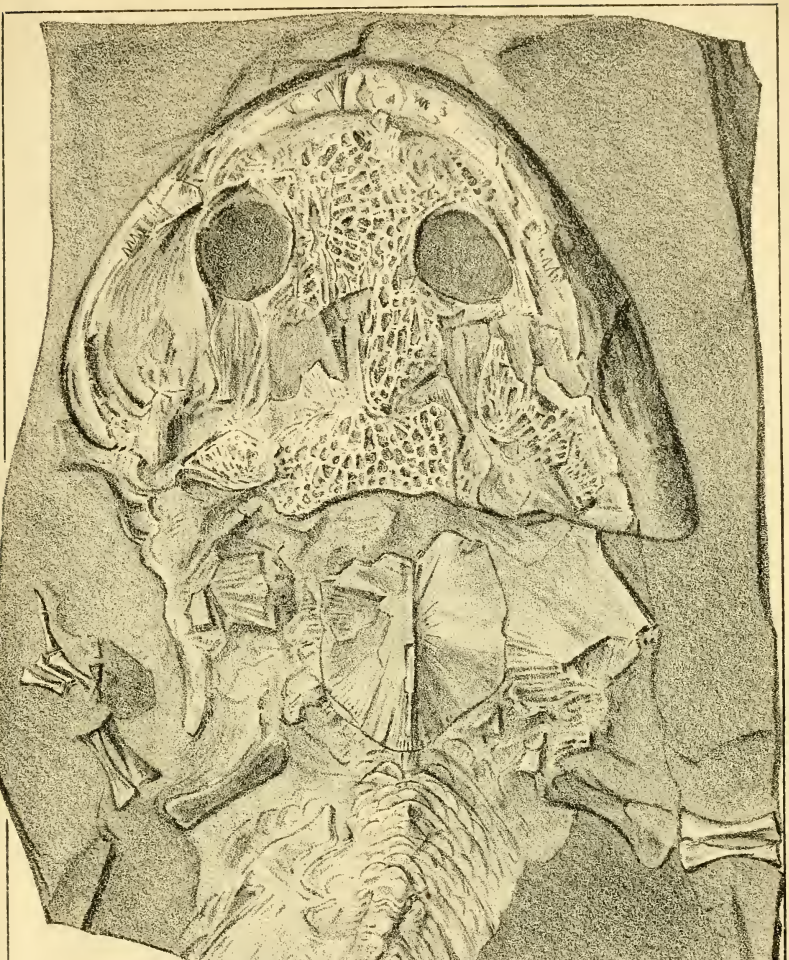
Name.	*Date of Election.*	*Present Address.*
2156. Ward, Lester F.	May 17, 1889,	1464 Rhode Island Ave., Washington, D. C.
2359. Warfield, Ethelbert D., Pres't	Dec. 17, 1897,	Easton, Pennsylvania.
2033. Weil, Edward Henry	Jan'y 16, 1885,	1720 Pine St., Philadelphia.
2028. Weisbach, Prof. Dr. Albin.	Jan'y 16, 1885,	Bergakad, Freiberg, Saxony.
2286. Welch, William H., M.D.	May 15, 1896,	Johns Hopkins Univ., Baltimore, Md.
1639. Wharton, Joseph.	April 16, 1869,	P. O. Box 1332, Philadelphia.
1637. White, Andrew D., Professor.	April 16, 1869,	Cornell Univ., Ithaca, N. Y.
1848. White, Israel C., Professor	Jan'y 18, 1878,	West Virginia Univ., Morgantown, W. Va.
1863. Wilder, Burt G., Professor	May 3, 1878,	Cornell Univ., Ithaca, N. Y.
2250. Willcox, Joseph	Feb. 15, 1895,	The Gladstone, Philadelphia.
2347. Williams, Edward H., Jr., Prof.	Oct. 15, 1897,	Lehigh Univ., Bethlehem, Pa.
2114. Williams, Sir Monier-Monier.	Dec. 17, 1886,	Onslow Gardens, London S.W., England.
2151. Williams, Talcott	May 18, 1888,	916 Pine Street, Philadelphia.
2178. Willis, Henry, Professor	Feb'y 21, 1890,	4036 Baring St., Philadelphia.
2041. Wilson, James Cornelius, M.D.	Jan'y 16, 1885,	1437 Walnut St., Philadelphia.
1747. Wilson, Joseph M.	Jan'y 16, 1874,	1036 Drexel Building, Phila.
2137. Wilson, William P., M.D.	May 20, 1887,	640 N. 32d St., Philadelphia.
2341. Wilson, Woodrow, Professor	Oct. 15, 1897,	Princeton, N. J.
2220. Wistar, Gen. Isaac J.	May 19, 1893,	269 Broad Street Station, Phila.
2314. Wister, Owen	May 21, 1897,	328 Chestnut Street, Phila.
2343. Witmer, Lightner, Professor.	Oct. 15, 1897,	University of Penna., Phila.
1884. Wood, Richard.	April 18, 1879,	1620 Locust St , Philadelphia.
1762. Woodward, Henry.	July 17, 1874,	British Museum, London S.W., England.
1751. Wootten, J. E.	Jan'y 16, 1874,	226 N. 6th Ave., Reading, Pa.
2290. Wright, Arthur W., Professor.	May 15, 1896,	Yale Univ., New Haven, Conn.
2244. Wundt, William, Professor.	Feb. 15, 1895,	Leipzig, Germany.
1932. Wurts, Dr. Charles Stewart.	Jan'y 21, 1881,	1701 Walnut St., Philadelphia.
2061. Wyckoff, Lieut. A. B.	Feb'y 19, 1886,	North Yakima, Washington.

Y

1904. Yarnall, Ellis	April 16, 1880,	105 S. Front St , Philadelphia.
1759. Young, Charles Augustus, Prof.	April 17, 1874,	Princeton, N. J.

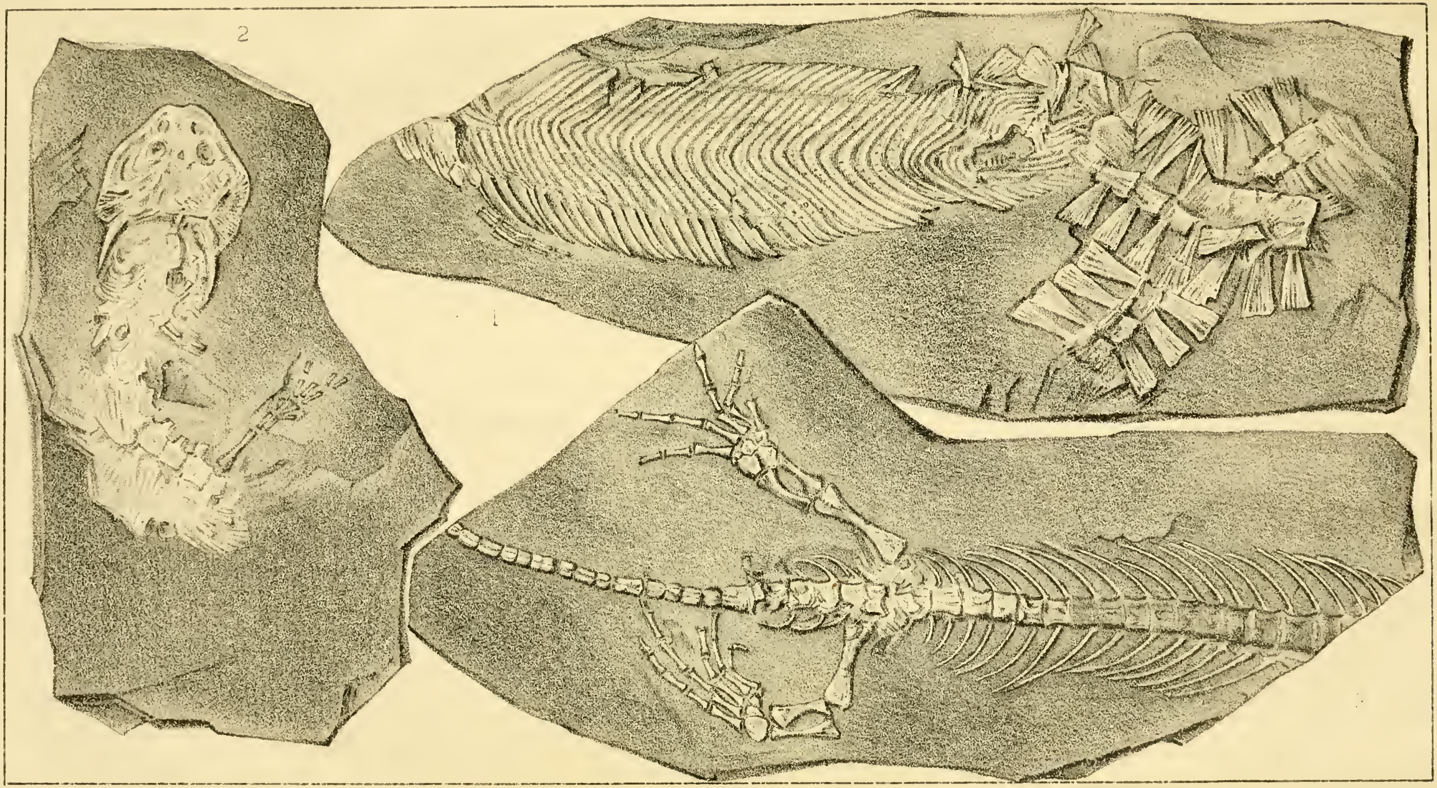


Scales of Sagenodus. Natural size.



1-3. Scales of HOLOPTYCHIUS. 4. SAUROPLEURA LATITHORAX.

PLATE III



1. CTENERPETON FOVEOLATUM. 2. CERATERPETON TENUICORNE. 3. ISODECTES PUNCTULATUS.

Australian Rock Carvings.

PLATE V (half size).—Illuminated leaflet in the possession of Henry W. Gross, of Doylestown. The floriated text is Luther's translation of John xix, 18. *Allda Kreuzigten sie Ihn,* etc., etc. Below it is a bar of music with red lines heading a hymn of six verses beginning "*O fröhliche Stunden O herrliche Zeit,*" and beneath an alphabet and numeral series. A pious rhyme beginning "*Ach lieber Mensch*" forms the lower, left border. Colors red, black, blue, yellow, brown and green.

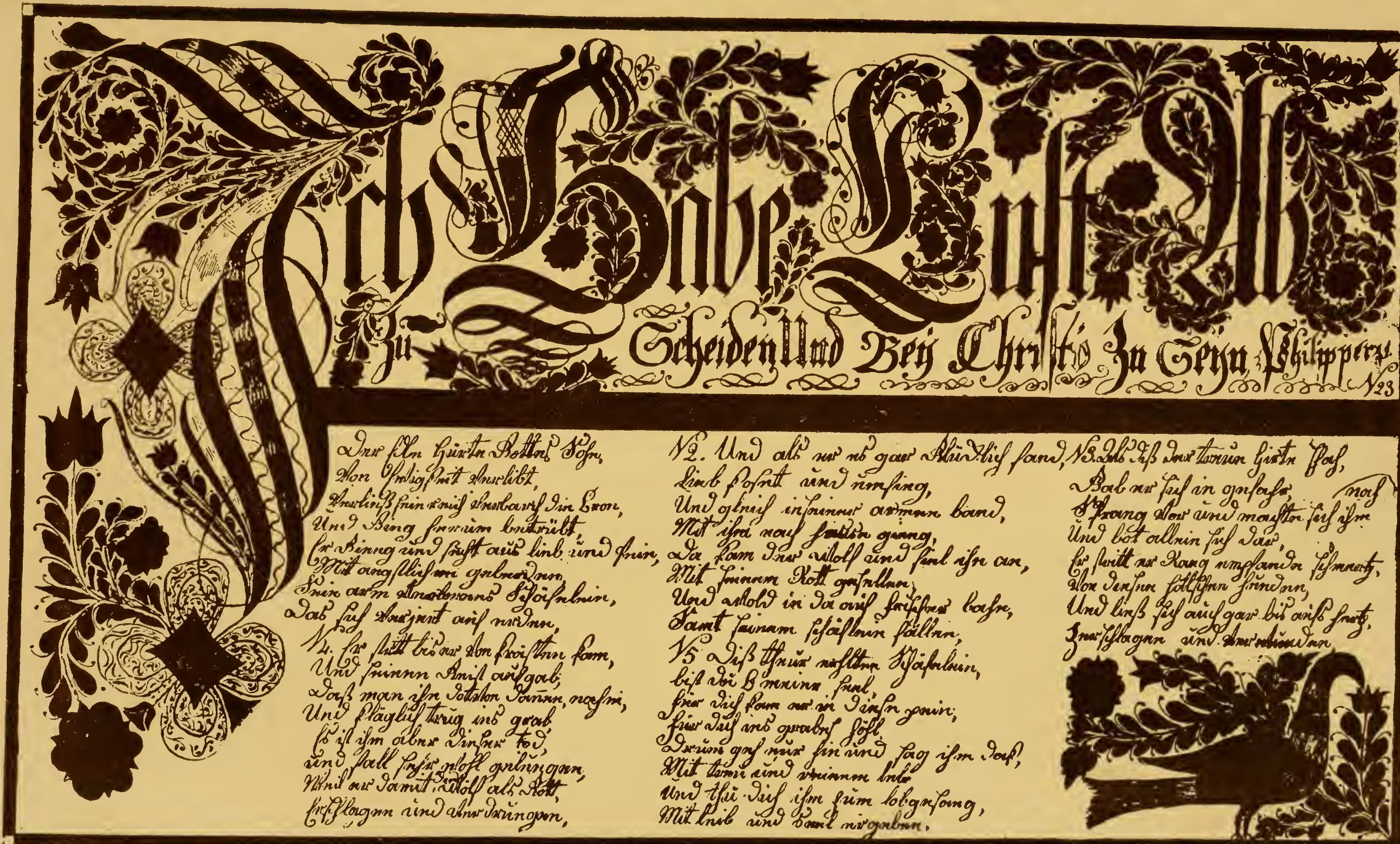



PLATE VI.—Illuminated leaflet with text in Philippians i, 23, and hymn. In possession of Henry K. Gross, of Plumsteadville.

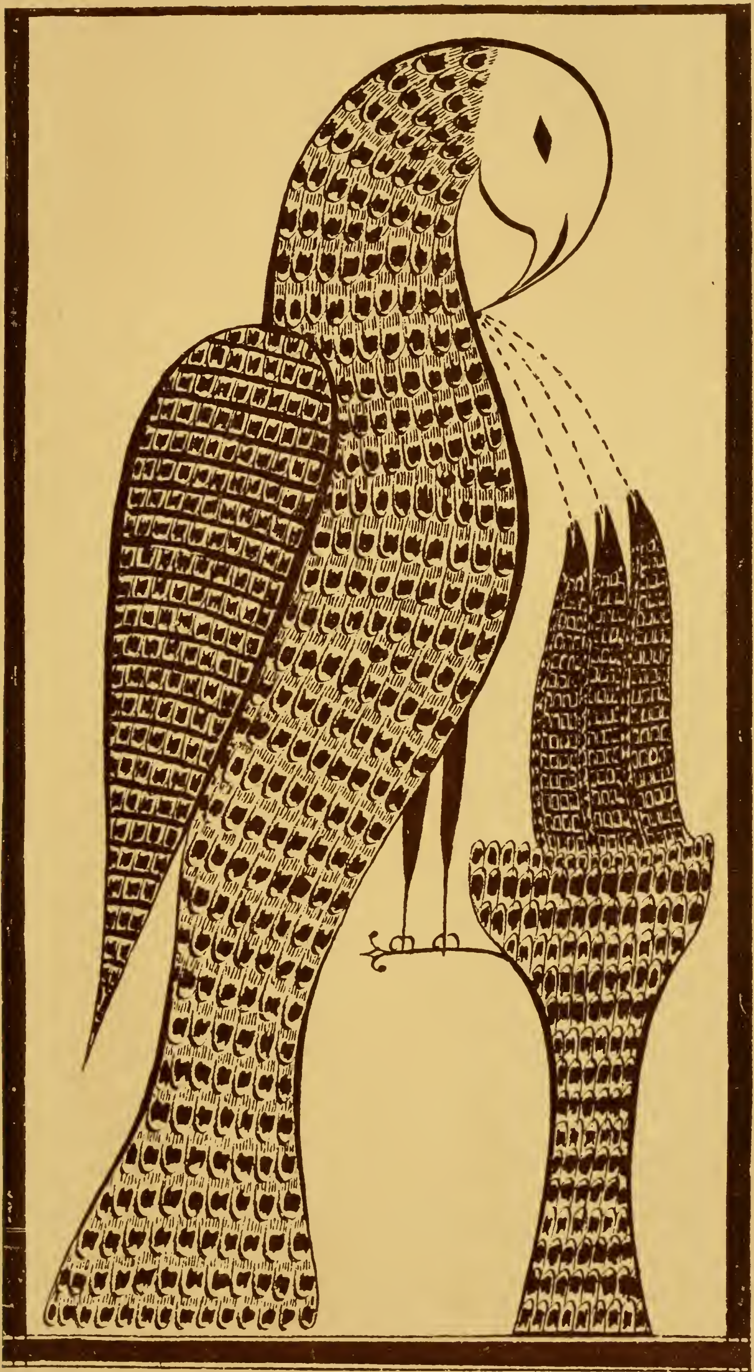


PLATE VIII.—The Pelican feeding its young with its blood. Sacred symbolic design in possession of Henry K. Gross, of Plumsteadville.

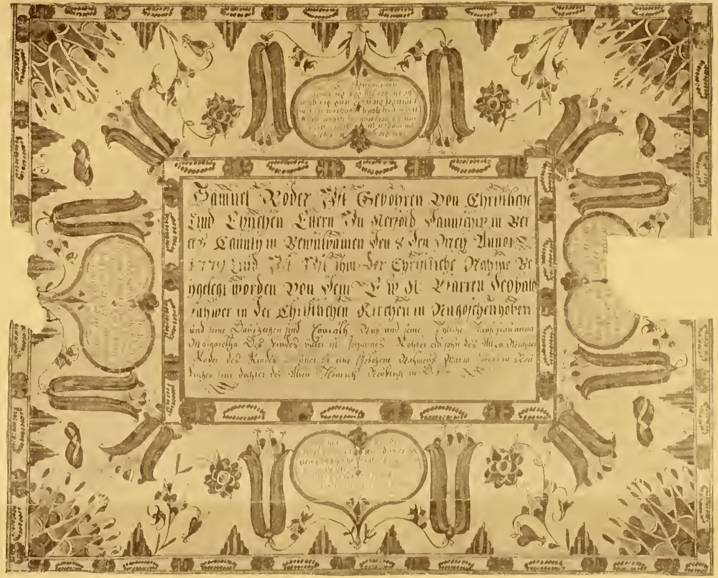
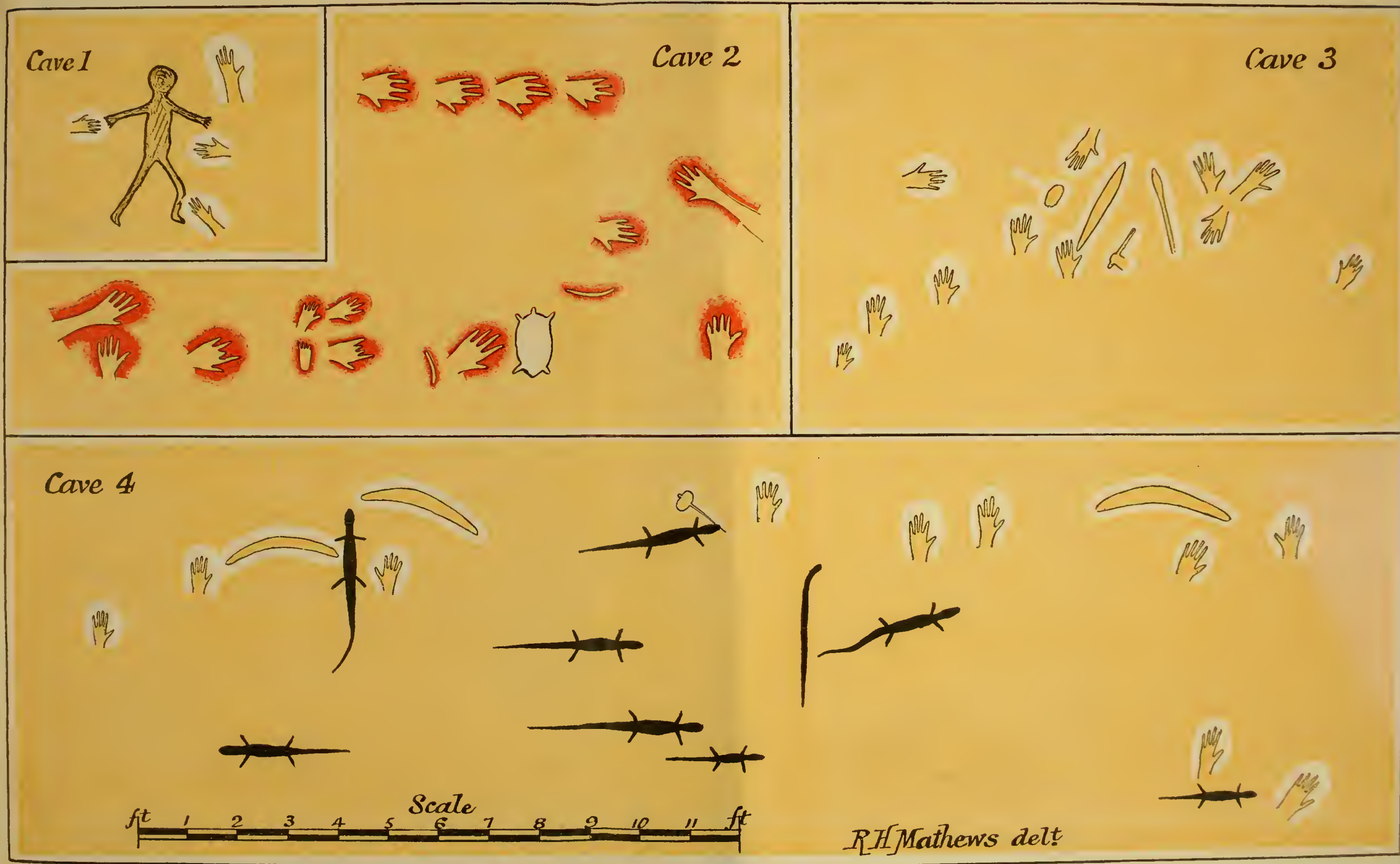


PLATE IX (about two-fifths).—Samuel Roeder's Taufscheine, 1779, showing the Heart and Tulip decoration. In possession of the Bucks County Historical Society. Deposited by Nathan C. Roeder, of Shinnerstown, Bucks County, Pennsylvania.


Cave 1
Cave 2
Cave 3
Cave 4
Scale
ft 1 2 3 4 5 6 7 8 9 10 11 ft
R H Mathews delt

PROCEEDINGS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY,

HELD AT PHILADELPHIA, FOR PROMOTING USEFUL KNOWLEDGE.

VOL. XXXVI. 4248 JANUARY, 1897. NO. 154.

CONTENTS.

PHILADELPHIA :

THE AMERICAN PHILOSOPHICAL SOCIETY,

104 South Fifth Street,

1897.

No. 153 of the PROCEEDINGS, completing Volume xxxv for the year 1896, is not yet published, but will be issued shortly.

It is requested that all correspondence be addressed

To the Secretaries of the

AMERICAN PHILOSOPHICAL SOCIETY,

104 South Fifth Street,

Philadelphia, U. S. A.

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MAGELLANIC PREMIUM.

FOUNDED IN 1786, BY
JOHN HYACINTH DE MAGELLAN,
OF LONDON.

1897.

THE AMERICAN PHILOSOPHICAL SOCIETY,

Held at Philadelphia, for Promoting Useful Knowledge,

ANNOUNCES THAT IN

DECEMBER, 1897,

IT WILL AWARD ITS

MAGELLANIC GOLD MEDAL

to the author of the best discovery, or most useful invention, relating to Navigation, Astronomy, or Natural Philosophy (mere natural history only excepted) under the following conditions:

1. The candidate shall, on or before November 1, 1897, deliver, free of postage or other charges, his discovery, invention or improvement, addressed to the President of the American Philosophical Society, No. 104 South Fifth Street, Philadelphia, U. S. A., and shall distinguish his performance by some motto, device, or other signature. With his discovery, invention, or improvement, he shall also send a sealed letter containing the same motto, device, or signature, and subscribed with the real name and place of residence of the author.
2. Persons of any nation, sect or denomination whatever, shall be admitted as candidates for this premium.
3. No discovery, invention or improvement shall be entitled to this premium, which hath been already published, or for which the author hath been publicly rewarded elsewhere.
4. The candidate shall communicate his discovery, invention or improvement, either in the English, French, German, or Latin language.
5. A full account of the crowned subject shall be published by the Society, as soon as may be after the adjudication, either in a separate publication, or in the next succeeding volume of their Transactions, or in both.
6. The premium shall consist of an oval plate of solid standard gold of the value of ten guineas, suitably inscribed, with the seal of the Society annexed to the medal by a ribbon.

All correspondence in relation hereto should be addressed

TO THE SECRETARIES OF THE

AMERICAN PHILOSOPHICAL SOCIETY,

NO. 104 SOUTH FIFTH STREET,

PHILADELPHIA, U. S. A.

PROCEEDINGS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY,

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VOL. XXXVI. 4248. MAY, 1897. NO. 155.

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American Philosophical Society,

104 South Fifth Street,

Philadelphia, U. S. A.

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Magellanic Premium.

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JOHN HYACINTH DE MAGELLAN,
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1897.

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MAGELLANIC GOLD MEDAL

to the author of the best discovery, or most useful invention, relating to Navigation, Astronomy, or Natural Philosophy (mere natural history only excepted) under the following conditions:

1. The candidate shall, on or before November 1, 1897, deliver, free of postage or other charges, his discovery, invention or improvement, addressed to the President of the American Philosophical Society, No. 104 South Fifth Street, Philadelphia, U. S. A., and shall distinguish his performance by some motto, device, or other signature. With his discovery, invention, or improvement, he shall also send a sealed letter containing the same motto, device, or signature, and subscribed with the real name and place of residence of the author.
2. Persons of any nation, sect or denomination whatever, shall be admitted as candidates for this premium.
3. No discovery, invention or improvement shall be entitled to this premium, which hath been already published, or for which the author hath been publicly rewarded elsewhere.
4. The candidate shall communicate his discovery, invention or improvement, either in the English, French, German, or Latin language.
5. A full account of the crowned subject shall be published by the Society, as soon as may be after the adjudication, either in a separate publication, or in the next succeeding volume of their Transactions, or in both.
6. The premium shall consist of an oval plate of solid standard gold of the value of ten guineas, suitably inscribed, with the seal of the Society annexed to the medal by a ribbon.

All correspondence in relation hereto should be addressed

TO THE SECRETARIES OF THE

AMERICAN PHILOSOPHICAL SOCIETY,

NO. 104 SOUTH FIFTH STREET,

PHILADELPHIA, U. S. A.

PROCEEDINGS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY

HELD AT PHILADELPHIA FOR PROMOTING USEFUL KNOWLEDGE.

VOL. XXXVI. DECEMBER, 1897. NO. 156.

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PHILADELPHIA:

THE AMERICAN PHILOSOPHICAL SOCIETY,

104 South Fifth Street,

1898.

Henry M. Phillips Prize Essay.

PHILADELPHIA, 104 SOUTH FIFTH STREET,
APRIL 5, 1897.

THE AMERICAN PHILOSOPHICAL SOCIETY held at Philadelphia for Promoting Useful Knowledge has the honor to announce that an award of the Henry M. Phillips Prize will be made during the year 1899; essays for the same to be in the possession of the Society before the first day of May, 1899. The subject upon which essays are to be furnished by competitors is:

The development of the law, as illustrated by the decisions relating to the police power of the State.

The essay shall not contain more than one hundred thousand words, excluding notes. Such notes, if any, should be kept separate as an Appendix.

The Prize for the crowned essay will be two thousand dollars lawful gold coin of the United States, to be paid as soon as may be after the award. The Society invites attention to the regulations governing said prize, which accompany this circular.

William V. McKean, Craig Biddle, Mayer Sulzberger, C. Stuart Patterson, Joseph C. Fraley, Frederick Fraley, *President of the Society, Horace Jayne, M.D.,* Treasurer of the Society, Committee on the Henry M. Phillips Prize Essay Fund.*

The essays must be sent, addressed to Frederick Fraley, President of the American Philosophical Society, Philadelphia.

* Elected Treasurer American Philosophical Society, January 7, 1898, in place of J. Sergeant Price, Esq., deceased, August 16, 1897.

REGULATIONS.

Competitors for the prize shall affix to their essays some motto or name (not the proper name of the author, however), and when the essay is forwarded to the Society it shall be accompanied by a sealed envelope, containing within, the proper name of the author, and, on the outside thereof, the motto or name adopted for the essay.

At a stated meeting of the Society, in pursuance of the advertisement, all essays received up to that time shall be referred to a Committee of Judges, to consist of five persons, who shall be selected by the Society from nomination of ten persons made by the Standing Committee on the Henry M. Phillips Prize Essay Fund.

Essays may be written in English, French, German, Dutch, Italian, Spanish or Latin; but, if in any language except English, must be accompanied by an English translation of the same.

No treatise or essay shall be entitled to compete for the prize that has been already published or printed, or for which the author has received already any prize, profit, or honor, of any nature whatsoever.

All essays must be *clearly* and *legibly* written or printed on one side of the paper only.

The literary property of such essays shall be in their authors, subject to the right of the Society to publish the crowned essay in its Transactions or Proceedings.

MAGELLANIC PREMIUM.

FOUNDED IN 1786, BY
JOHN HYACINTH DE MAGELLAN,
OF LONDON.

1898.

THE AMERICAN PHILOSOPHICAL SOCIETY,

Held at Philadelphia, for Promoting Useful Knowledge

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