

THOMAS K. PAULEY  
Biology Department

# West Virginia University Bulletin

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SERIES No. 30, No. 1.

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## PROCEEDINGS OF THE WEST VIRGINIA ACADEMY OF SCIENCE

Volume 3



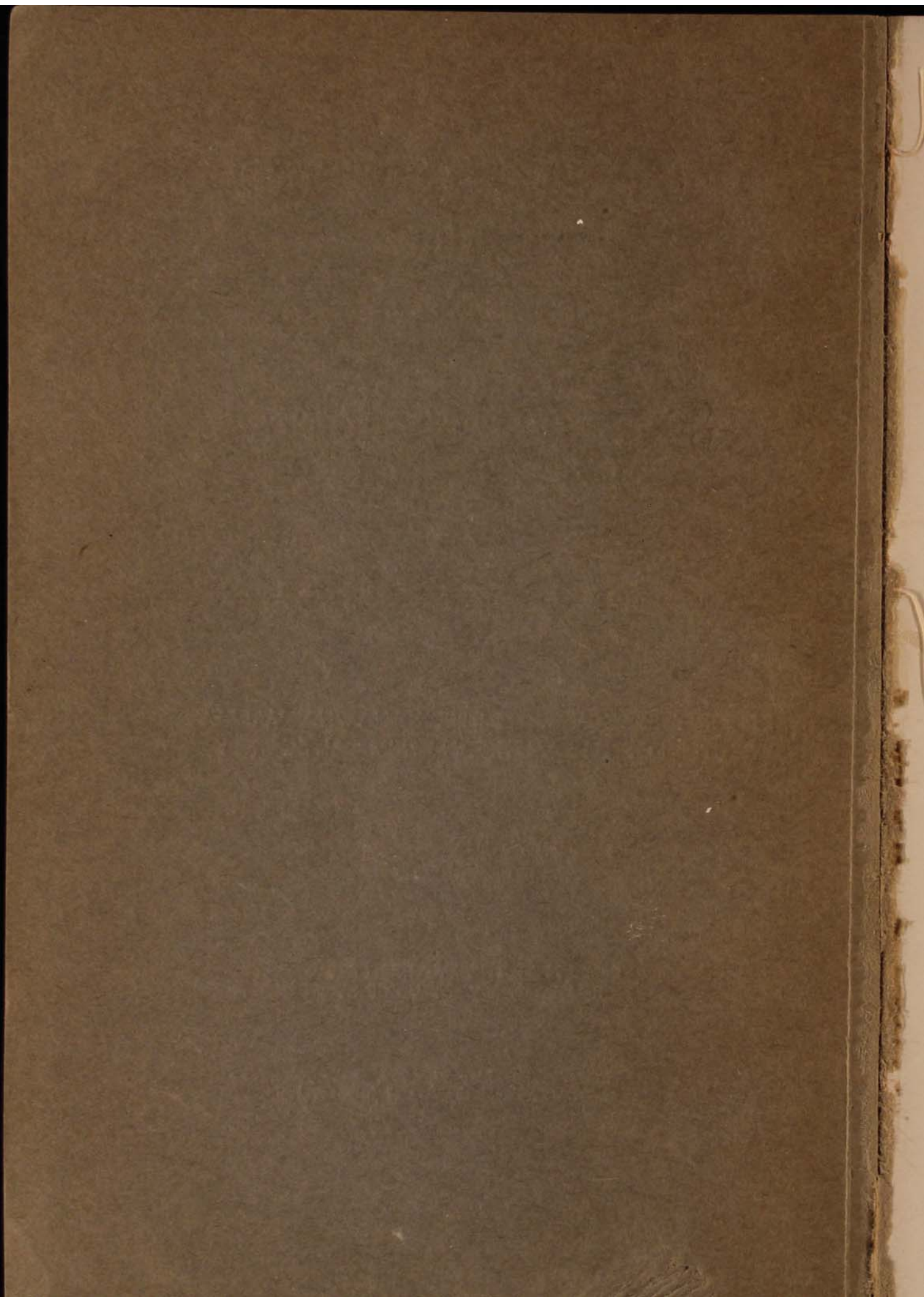
August, 1929

IN JOINT SESSION WITH THE KANAWHA VALLEY  
SECTION OF THE AMERICAN CHEMICAL SOCIETY

Published by THE UNIVERSITY  
MORGANTOWN, WEST VIRGINIA

Entered as second class matter, May 27, 1909, at the postoffice at  
Morgantown, W. Va., under the Act of July 16, 1904.

Issued twice in October, December, February, April, and June,  
and once in each other month.



PROCEEDINGS  
OF THE WEST VIRGINIA  
ACADEMY OF SCIENCE

Volume 3



August, 1929

Sixth Annual Session

WATSON

My dear Mother

I received your letter of the 10th

and was glad to hear from you

and to hear that you were all

well and happy. I am well

and hope these few lines will

find you all the same. I am

very affectionately yours

Watson

P.S. I am sorry I cannot

write you more often

but I am very busy

at present. I am

very affectionately yours

Watson

P.S. I am sorry I cannot

write you more often

but I am very busy

at present. I am

very affectionately yours

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OFFICERS OF THE WEST VIRGINIA ACADEMY  
OF SCIENCE

OFFICERS OF THE SIXTH ANNUAL MEETING

Charleston, April 26-27, 1929.

President.....	John L. Tilton, Morgantown
Vice-President.....	H. F. Rogers, Fairmont
Secretary.....	P. D. Strausbaugh, Morgantown
Treasurer.....	H. T. McKinney, Bethany
Curator.....	John E. Winter, Morgantown

Chairmen of Sections

Biology.....	S. Benton Talbott
Chemistry.....	Carl G. Campbell
Geology and Mining.....	C. E. Lawall
Mathematics and Physics.....	Robert C. Colwell
Social Sciences.....	John E. Winter

Editorial Committee for Volume Three:—H. F. Rogers, P. D. Straus-  
baugh, John L. Tilton, and John E. Winter.

MEMBERS OF THE WEST VIRGINIA ACADEMY  
OF SCIENCE\*

May 1, 1929.

- Albert, C. E., Dean of Davis and Elkins College, Elkins.
- \*Ammons, Nelle P., Instructor in Botany, W. V. U., Morgantown.
- \*Bancroft, Dr. George R., Professor of Chemistry, W. V. U., Morgantown.
- Beeler, Charles, Student of Chemistry, Fairmont Teachers' College, Fairmont.
- Bergy, Prof. Gordon A., Professor of Pharmacy, W. V. U., Morgantown.
- Bibbee, P. C., Professor of Biology, Concord State Normal College, Athens.
- Bland, V. K., Teacher of Biology, Weston High School, Weston.
- \*Bleininger, Dr. A. V., Physician, Newell.
- Bloss, Dr. James R., 418 Eleventh Street, Huntington.
- \*Bourn, W. S., Boyce Thompson Institute, Yonkers, New York.
- Brock, Clarence, Teacher of Chemistry, East Side Fairmont High School, Fairmont.
- \*Brooks, Fred E., Entomologist, French Creek.
- Brooks, A. B., Park Naturalist, Oglebay Park, Wheeling, W. Va.
- Brooks, Maurice, Teacher of Biology, French Creek.
- Brown, Russell G., Graduate Student, W. V. U., Morgantown.
- Burgess, Miss Frances C., Professor of Geography, Marshall College, Huntington.
- \*Campbell, Carl G., Professor of Chemistry, Marshall College, Huntington.
- Chapman, Daisy V., Teacher of Biology, Williamson.
- Chase, E. F., Philippi.
- \*Chidester, Dr. F. E., Professor of Zoology, W. V. U., Morgantown.
- \*Clark, Dr. Friend E., Professor of Chemistry, W. V. U., Morgantown.
- \*Colwell, Dr. R. C., Professor of Physics, W. V. U., Morgantown.
- \*Colwell, Rachel H., Professor of Home Economics, W. V. U., Morgantown.
- Cook, Rollo V., Professor of Physics, Bethany College, Bethany.
- Cook, William A., State Superintendent of Schools, Charleston.
- \*Core, Earl L., Instructor in Botany, W. V. U., Morgantown.
- \*Cramblett, W. H., Professor of Mathematics, Bethany College, Bethany.
- \*Cunningham, Dr. Holly E., Professor of Philosophy, W. V. U., Morgantown.
- Cutright, Frank, Professor of Biology, Concord State Normal, Athens.
- Cutright, Paul R., Professor of Biology, Geneva College, Beaver Falls, Penna.

- Dadisman, Dr. A. J., Professor of Farm Economics, W. V. U., Morgantown.
- \*Davies, Dr. E. C. H., Professor of Chemistry, W. V. U., Morgantown.
- \*Davis, Hannibal, Professor of Mathematics, W. V. U., Morgantown.
- Dodd, D. R., Department of Agronomy, W. V. U., Morgantown.
- \*Dodds, G. S., Professor of Histology, W. V. U., Morgantown.
- \*Dustman, R. B., Chemist, West Virginia Experiment Station, Morgantown.
- Eddy, Zola M., Student of Mathematics, W. V. U., Morgantown.
- \*Eiesland, Dr. John A., Professor of Mathematics, W. V. U., Morgantown.
- Fenton, Dr. C. C., Professor of Pathology, W. V. U., Morgantown.
- Forman, Dr. A. H., Professor of Electrical Engineering, W. V. U., Morgantown.
- Frame, Nat T., Director of Agricultural Extension, Morgantown.
- Franzheim, Charles Mertz, Wheeling.
- \*Fromme, Dr. F. D., Dean College of Agriculture, W. V. U., Morgantown.
- \*Galpin, Dr. Sidney L., Professor of Geology, W. V. U., Morgantown.
- \*Garber, Dr. R. J., Professor of Agronomy, W. V. U., Morgantown.
- Garrett, R. W., Professor of European History, Bethany College Bethany.
- \*Giddings, Dr. N. J., Professor of Plant Pathology, W. V. U., Morgantown.
- Gilbert, Dr. Frank A., Professor of Botany, Marshall College, Huntington.
- Gwynn, C. W., Professor of Education, Davis and Elkins College, Elkins.
- Hackney, Lillian, Professor of Mathematics, Marshall College, Huntington.
- Hadden, Mildred, 1300 Virginia Street, Charleston.
- Hammond, Elmer L., Assistant Professor of Pharmacy, W. V. U., Morgantown.
- \*Harris, Dr. T. L., Professor of Sociology, W. V. U., Morgantown.
- Harshbarger, Jennie, Instructor in Biology, Fairmont High School, Fairmont.
- Haught, C. D., Professor of Physics, Fairmont State Teachers' College, Fairmont.
- \*Hearne, Julius G., Wheeling.
- Hill, George H., Road Engineer, Charleston.
- Hodge, W. W., Professor of Chemical Engineering, W. V. U., Morgantown.
- Holland, Claude L., 400 Locust Avenue, Fairmont.
- H'ron, Ralph P., Professor of Physics, Marshall College, Huntington.
- Honor, R. R., Normal Gas Company, Clarksburg.
- Hunter, J. Ross, Physician, 1013 Quarrier Street, Charleston.
- Hussel, John, 1105 Fourteenth Street, Huntington.

- \*Jacobson, Dr. C. A., Professor of Chemistry, W. V. U., Morgantown.  
Johnson, R. W., Assistant Professor of Chemistry, W. V. U., Morgantown.
- \*Jones, C. R., Dean, College of Engineering, W. V. U., Morgantown.  
\*Jones, Harris A., Meteorologist, Elkins.  
Judy, W. D., Clarksburg.  
Kaplan, D. B., Chemist, Morgantown.  
Kee, George, Student of Chemistry, Fairmont State Teachers' College, Fairmont.  
Knight, Dr. H. G., Chief, Bureau of Soils and Chemistry, Washington, D. C.  
Lang, Thomas Simeon, City Engineer, Clarksburg.  
Lawall, Charles E., Professor of Mining Engineering, W. V. U., Morgantown.
- Leitch, Dr. Andrew, Professor of Psychology, Bethany College, Bethany.  
Lively, E. L., State Teachers' College, Fairmont.  
Long, Virginia Dare, Teacher of Biology, Burnsville.  
Loy, Melvin P., Department of Zoology, Marshall College, Huntington.  
Maxwell, C. W., Attorney, Elkins.  
McClure, Iris, 400 Beverly Avenue, Morgantown.  
McGovran, E. R., Teacher, 835 Edgewood Ave., Charleston.  
\*McKinney, Dr. H. T., Professor of Education, Bethany College, Bethany.  
McMillan, Herbert, Department of Chemistry, Morgantown High School, Morgantown.  
McNeill, E. Meade, Instructor in Biology, Concord State Normal School, Athens.  
Meharge, Laurence, Hazel Atlas Glass Company, Wheeling.
- \*Molby, Dr. F. A., Professor of Physics, W. V. U., Morgantown.  
Morgan, John J., Charleston Electric Supply Co., Charleston.  
Montgomery, John G., Jr., 308 Seneca Street, Oil City, Penna.  
Newcombe, Curtis L., Graduate Student, W. V. U., Morgantown.  
\*Odland, T. E., Department of Agronomy, W. V. U., Morgantown.  
Palmer, Neva, Graduate Student, W. V. U., Morgantown.  
Parrack, H. O., Graduate Student, W. V. U., Morgantown.  
\*Phelps, Dr. Edward, Professor of Chemistry, Marshall College, Huntington.
- \*Price, Andrew, Attorney, Marlinton.  
Price, Paul H., State Geological Survey, Cornell University, Ithaca, N. Y.  
\*Purdum, R. B., Professor of Physics, Davis and Elkins College, Elkins.  
Ramage, Dr. C. M., Fairmont.  
Raub, Leo G., Professor of Physics, New River State School, Montgomery.  
\*Reese, Dr. A. M., Professor of Zoology, W. V. U., Morgantown.  
\*Reger, David B., State Geological Survey, Morgantown.  
\*Reynolds, C. N., Associate Professor of Mathematics, W. V. U., Morgantown.

- Rhodes, T. Thayer, Teacher of Science, Sandyville.
- Richards, Margaret, Teacher of Biology, Morgantown High School, Morgantown.
- \*Rogers, H. F., Chemistry, Fairmont State Teachers' College, Fairmont.
- Rohr, H. D., Principal, Weston High School, Weston.
- Saleski, R. E., Professor of German, Bethany College, Bethany.
- Sargent, R. J., Dean, Marshall College, Huntington.
- Scott, S. A., Vice Pres., New River Coal Co., McDonald.
- Sharp, Ward M., Graduate Student, W. V. U., Morgantown.
- Shawkey, Dr. M. P., President, Marshall College, Huntington.
- Shaw, D. A., Gilbert.
- Shouse, J. B., Dean, Teachers' College, Marshall College, Huntington.
- Simpson, Dr. John M., Dean, Medical College, W. V. U., Morgantown.
- Skuce, Thomas W., Extension Forester, Morgantown.
- \*Spangler, Dr. R. C., Professor of Botany, Morgantown.
- Spelman, H. J., State Road Commission, Box 426, Huntington.
- Spray, Dr. Robert S., Associate Bacteriologist, Morgantown.
- Staab, W. A., Professor of Mining Engineering, W. V. U., Morgantown.
- Stathers, Allan, Teacher of Mathematics, Weston High School, Weston.
- Stayman, Joseph W., President, Potomac State School, Keyser.
- Stout, Wilbur, Geological Survey, Columbus, Ohio.
- \*Straley III, H. W., Princeton.
- \*Strausbaugh, Dr. P. D., Professor of Botany, W. V. U., Morgantown.
- Sumpstine, Wilbur J., Bethany College, Bethany.
- Talbott, S. Benton, Professor of Biology, Davis and Elkins College, Elkins.
- \*Taylor, Dr. Leland H., Professor of Biology, W. V. U., Morgantown.
- \*Tilton, Dr. John L., Professor of Geology, W. V. U., Morgantown.
- \*Tucker, R. C., Box 265, Morgantown.
- \*Turner, Dr. Bird M., Associate Professor of Mathematics, W. V. U., Morgantown.
- Turner, Dr. John R., President, West Virginia University, Morgantown.
- Utterback, W. I., Professor of Zoology, Marshall College, Huntington.
- Wade, Dr. S. S., Physican, Morgantown.
- Wagner, John R., Glenville.
- \*Weimer, Dr. B. R., Professor of Biology, Bethany College, Bethany.
- Welch, Dr. George B., Professor of Physics, Marshall College, Huntington.
- White, Bennett S., Professor of Drawing and Designing, W. V. U., Morgantown.
- White, Ryland, Student Fairmont State Teachers' College, Fairmont.
- \*Winter, Dr. John E., Professor of Psychology, W. V. U., Morgantown.
- \*Wolfe, H. S., Assistant Professor of Botany, W. V. U., Morgantown.
- Woolery, W. K., Professor of American History, Bethany College, Bethany.

\*Workman, A. C., Dean, Bethany College, Bethany.

\*Yeaton, Walter, Professor of Geology, W. V. U., Morgantown.

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\*Names of members who are also members of the American Association for the Advancement of Science.

CONSTITUTION OF THE WEST VIRGINIA  
ACADEMY OF SCIENCE

ARTICLE I.—**Name.** This organization shall be known as The West Virginia Academy of Science.

ARTICLE II.—**Object.** The object of the Academy of Science shall be the encouragement of scientific work in the State of West Virginia.

ARTICLE III.—**Membership.** Membership of this Academy shall consist of active members and corresponding members. Active members shall be residents of the State of West Virginia who are interested in scientific work. They shall be of two classes, to wit: National members, who are members of the American Association for the Advancement of Science as well as of the West Virginia Academy of Science, and Local Members, who are members of the West Virginia Academy of Science but not of the Association.

Corresponding members shall be persons who are actively engaged in scientific work not resident in the State of West Virginia. They shall have the same privileges and duties as Active Members.

For election to any class of membership the candidates must have been nominated in writing by two members, one of whom must know the applicant personally; receive a majority vote of the executive committee and a three-fourths vote of the members of the Academy, present at any session.

ARTICLE IV.—**Fees.** Each active member shall pay in advance an annual fee of one dollar (\$1.00) to the Treasurer of the Academy, due at each annual meeting; and in addition, each new member shall pay an initiation fee of one dollar (\$1.00) due at the time of election to membership.

Corresponding members are exempt from dues. (As enacted by the Academy at the Elkins meeting, May 19, 1928.)

ARTICLE V.—**Officers.** The officers of the Academy shall be a president, a vice-president, secretary and a treasurer. These officers shall be elected at the annual meeting from the active members in good standing on the recommendation of a nominating committee of three appointed by the president.

The executive committee consisting of the four above officers and the president of the previous year shall have the authority to fix the time and place of meetings and to transact such other business as may need attention between the meetings of the Academy.

The secretary and treasurer only shall be eligible to re-election for consecutive terms. The term of the secretary shall be three years. (Provided for in amendment to constitution authorized by the Academy in West Virginia University meeting November 26, 1927).

ARTICLE VI.—**Standing Committees.** The standing committees shall be as follows:

A Committee on Membership appointed annually by the President consisting of three members.

A Committee on Publications consisting of the President, Secretary, and a third member chosen annually by the Academy.

ARTICLE VII.—**Meetings.** The regular meetings of the Academy shall be held at such time and place as the executive committee may select. The executive committee may call a special session, and a special session shall be called at the written request of twenty members.

ARTICLE VIII.—**Publications.** The Academy shall publish its transactions and papers which the Committee on Publications deem suitable. All papers presented to the Academy for publication shall be of a scientific nature. All members shall receive the publications of the Academy gratis.

Each section is empowered to perfect its own organization as limited by the Constitution and By-Laws of the Academy.

ARTICLE IX.—**Amendments.** This Constitution may be amended at any regular annual meeting by a three-fourths vote of all active members present, provided a notice of said amendment has been sent to each member ten days in advance of the meeting.

## BY-LAWS

I.—The following shall be the order of business:

1. Call to order.
2. Reports of Officers.
3. Reports of Executive Committees.
4. Reports of Standing Committees.
5. Election of Members.
6. Reports of Special Committees.
7. Appointment of Special Committees.
8. Unfinished Business.
9. New Business.
10. Election of Officers.
11. Program.
12. Adjournment.

II.—No meeting of this Academy shall be held without thirty days' notice having been given by the Secretary to all members.

III.—Twelve members shall constitute a quorum of the Academy for the transaction of business. Three of the Executive Committee shall constitute a quorum of the Executive Committee.

IV.—No bill against the Academy shall be paid without an order signed by the President and Secretary.

V.—Members who shall allow their dues to be unpaid for two years, having been annually notified of their arrearage by the Treasurer, shall have their names stricken from the roll.

VI.—The President shall annually appoint an auditing committee of three who shall examine and report in writing upon the account of the Treasurer.

The financial year shall end at 9 o'clock in the morning of the first day of the annual meeting after which time the books shall be available to the Auditing Committee. (Enacted by the Academy at the Charleston meeting April 27, 1929).

In case a section adjourns without elevating a chairman for the succeeding meeting, and in case the chairmanship of a section becomes vacant between meetings through removal of the Chairman from the state or otherwise, the President of the Academy shall appoint the chairman for the next meeting of the section, and do so at as early a date as possible. (By action of the Academy in West Virginia University meeting November 26, 1927).

VII.—These by-laws may be amended or suspended by a two-thirds vote of the members present at any meeting.

MINUTES OF THE WEST VIRGINIA ACADEMY  
OF SCIENCE

April 26 and 27, 1929.

The sixth annual meeting of the West Virginia Academy of Science was held in joint session with the Kanawha Valley Section of the American Chemical Society, in Hotel Kanawha, Charleston, April 26 and 27, 1929.

On Friday at 12 o'clock the members of the Academy lunched with the members of the Rotary Club of Charleston, at which time Dr. Roger Adams of the University of Illinois gave a brief talk concerning his work dealing with the synthesis of organic compounds that may be effective as remedies for leprosy.

The opening session of the Academy was called to order shortly after 1 o'clock, President John L. Tilton presiding. The address of welcome was given by Mr. C. L. Voress, President of the Kanawha Valley Section of the American Chemical Society. Then after some announcements by President Tilton concerning the evening luncheon and the excursions planned for Saturday, the Secretary presented the report of the Executive Committee, which reads as follows:

1. Your committee has acted favorably upon the following applications for membership presented during the year. We recommend immediate approval of the entire list that all may feel free to take part in the business of the session; and we recommend that such dues as have been paid in advance be considered payments due at this time for the coming year:

John R. Turner, Morgantown.  
Maurice Brooks, French Creek.  
W. D. Judy, Clarksburg.  
Neva Palmer, Morgantown.  
Virginia Dare Long, Burnsville.  
Charles Mertz Franzheim, Wheeling.  
Professor Rollo V. Cook, Bethany College (Dept. Physics).  
D. R. Dodd, Morgantown.  
Melvin P. Loy, Dept. of Zoology, Marshall College.  
Frank A. Gilbert, Dept. of Botany, Marshall College.  
Daisy V. Chapman, Keyser.  
Zola M. Eddy, Morgantown.

Ward M. Sharp, Morgantown.

Prof. Frank Cutright, Athens (Concord Normal).

Prof. P. C. Bibbee, Athens (Concord Normal).

E. Meade McNeill, Athens (Concord Normal).

Russell G. Brown, Morgantown.

T. Thayer Rhodes, Teacher of Science, Sandyville.

Thos. Simeon Lang, City Engineer, Clarksburg.

Paul R. Cutright, Geneva College, Beaver Falls, Pa.

A. B. Brooks, Park Naturalist, Oglebay Park, Wheeling.

F. D. Fromme, Dean, College of Agriculture, W. V. U., Morgantown.

Leo G. Raub, Prof. of Physics, New River State School, Montgomery.

Mildred Hadden, 1300 Virginia Street, Charleston.

Van K. Bland, Teacher of Biology, Weston High School, Weston.

Allen Stathers, Teacher of Mathematics, Weston High School, Weston.

Margaret Richards, Teacher of Biology, Morgantown High School, Morgantown.

Iris McClure, 400 Beverly Avenue, Morgantown.

Wm. G. Webb, 503 Wheeling Steel Building, Wheeling.

Wm. A. Cook, State Superintendent of Schools, Charleston.

R. W. Johnson, Ass't Prof. of Chemistry, Bethany College.

W. K. Woolery, Prof. of American History, Bethany College.

R. W. Garrett, Prof. of European History, Bethany College.

C. D. Haught, Prof. of Physics, Fairmont Normal.

Frank S. White, Prof. of Psychology and Education, Fairmont Normal.

Clarence Brock, Teacher of Chemistry, East Side Fairmont High School.

George Kerr, Student of Chemistry, Fairmont Normal.

Chas. Beeler, Student of Chemistry, Fairmont Normal.

Ryland White, Student of Chemistry, Fairmont Normal.

Dr. Geo. B. Welch, Professor of Physics, Marshall College.

Miss Frances C. Burgess, Professor of Geography, Marshall College.

E. R. McGovran, Teacher, 835 Edgewood Avenue, Charleston.

2. In accordance with a requirement of the constitution notice was sent out January 23, 1929, in due time with reference to an addition proposed to Article VI of the By-Laws:

Resolved, That Section VI of the By-Laws be amended by the addition of the following after the first sentence of that article as it now reads:

The financial year shall end at nine o'clock in the morning of the

first day of the Annual Meeting, after which time the books shall be available to the Auditing Committee.

3. In the listing of sections we have taken the liberty to insert Astronomy along with Physics and Mathematics. We hope for your approval, that this insertion may be made in the future.

4. The constitution makes it the duty of the Executive Committee to decide where the next meeting of the Academy shall be held. It seems to us better to decide prior to an Annual Meeting where the following meeting shall be held, rather than leave it uncertain. We therefore recommend that the invitation of President Joseph W. Stayman for the Academy to hold its next Annual Meeting at Potomac State Sshool, Keyser, be accepted, said meeting to be held in the latter part of April, 1930.

5. In accordance with your decision at the Elkins Meeting, May 18, 1928, the reserve copies of volume one and two of the Proceedings are now in charge of the Librarian at the University of West Virginia, and the University through its Editor, Professor B. W. King, has reserved No. 1 of Series 30 for the Proceedings of the present meeting. Each writer is to receive 50 reprints of his paper. If he wishes covers and additional reprints he is to pay for the additional cost of them.

6. Our plan offering a prize for the best high school essay on the subject, "Out of Doors Where I Live," has met with somewhat of success. Nineteen essays were received from the following high schools, eleven in number:—Alderson, Beaver High School of Bluefield, Elk District, Elkins, Frankfort Junior H. S. of Alaska, Huntington, Junior H. S. at Meadow Creek, Morgantown, Moundsville, Pennsboro and Salem. We recommend that a similar prize be offered another year, with specific instructions that it shall go to the one who reveals the best knowledge either of the region as a whole in which the writer lives; i. e., its native trees and other flora, its wild life and their habits, its rocks and their position and contents, and the character of the scenery; or to any one or two of these topics, as the Academy may see fit to decide. An outline of such a plan is elsewhere presented.

Signed,

H. F. ROGERS,

B. R. WEIMER,

JOHN L. TILTON,

H. T. McKINNEY,

P. D. STRAUSBAUGH,

Executive Committee.

Each item of the report was considered separately and then the Academy adopted the report as a whole and ordered it to be included in the minutes. The items were disposed of in the following manner:

1. The secretary was instructed to cast the vote of the Academy for election to membership of all those whose names were presented.

2. The proposed change in Section VI of the By-Laws was approved.

3. The proposal to include astronomy in the Section of Physics and Mathematics was approved.

4. The Academy voted to accept the invitation of President Joseph W. Stayman to hold its next regular meeting at Potomac State School in Keyser, said meeting to be held in the latter part of April, 1930.

5. The proposed plan for the publication of the Proceedings was approved.

6. It was moved and seconded that a committee of five be appointed by the chair to make recommendations concerning the plan for the High School Prize Essay of another year and report to the Academy Saturday morning. This motion was passed and President Tilton appointed the committee as follows:

Dean A. C. Workman, Chairman. Maurice Brooks.  
D. B. Reger. J. A. Eiesland.  
J. E. Winter.

Following the adoption of the report of the Executive Committee the secretary was ordered to present the report of the Academy's delegate to the New York session of the Academy conference. The text of this report is given herewith:

The meeting of the delegates followed the first meeting of the Council of the American Association for the Advancement of Science. There were seventeen delegates present. On reorganization for this meeting and for the coming year the Secretary for the past year, Dr. Howard E. Enders of West Lafayette, Indiana, became chairman and Dr. D. W. Morehouse of Des Moines, Iowa, was elected Secretary, it being the understanding that the Secretary at this meeting would become the chairman of the meeting in Des Moines.

The general subject for discussion, as determined by previous Correspondence with the delegates, was announced to be, 'The Relation of the Affiliated Academies to the American Association.' Dr. M. W. Lyon, Jr., of the Indiana Academy of Science, was called upon to lead in the discussion. The substance of his prepared paper is given as follows:

How may the Academy Conference aid the affiliated academies for the advancement of science in their several regions? What can be done by the American Association, of which the conference is a special committee, to further this work and to enable affiliated societies to represent the aims and purposes of the Association as thoroughly as possible in their respective regions? The Association is ready to further the aims of the Conference in every feasible way, especially by furnishing means for circular communication and personal correspondence conducted by the Conference Secretary. Would it be desirable to inaugurate some sort of mimeographed bulletin that might be sent occasionally to all Conference members (and perhaps to all secretaries of affiliated academies), by which ideas and problems might be interchanged among the academies?

In the discussion that followed approval was expressed of the plan to have the Secretary of the American Association send out mimeographed bulletins on matters of interest to the academies, and to assist the academies in sending out their circular letters. It was thought especially desirable to send out circular letters to high school teachers of science urging them to attend the meetings of the academies and to invite good high school students to attend and even to present papers.

The business meeting was followed by a dinner given to the delegates.

While the above mentioned business meeting was the only one especially for the representatives of the state academies, the delegates were also members of the Council of the American Association for the Advancement of Science, and as such were entitled to vote on the various questions that arose, and to vote upon the election of officers of the general association and upon the chairman and secretary of the various Sections of the American Association for the Advancement of Science.

(Signed) JOHN L. TILTON,

Delegate for the West Virginia Academy of Science.

The report was accepted.

President Tilton then appointed the following committees. The President prefaced his appointment of the committees with the following explanation: "At the Elkins meeting it was voted that, 'Inasmuch as the present officers of the Academy had served for only six months, they be continued in office the ensuing year.' In making up the committees for the Charleston meeting I have as far as seemed possible held to the list of appointments made at the Elkins meeting."

Committee on Membership (the standing committee):

H. F. Rogers, Chairman, P. D. Strausbaugh, H. T. McKinney.

Committee on Resolutions:

David B. Reger, Chairman, H. F. Rogers, John A. Eiesland.

Auditing Committee:

C. E. Albert, Chairman, E. C. H. Davies, E. F. Chase.

Committee on Nominations:

B. R. Weimer, Chairman, Andrew Price, C. G. Campbell.

The President then asked the Vice-President, Prof. H. F. Rogers, to take the chair while the President's address was given. President Tilton gave an interesting paper on "The Trend of Geologic Thought," following which the various sections convened separately and the program announced for each section was carried out.

### PROGRAM

Sixth Annual Meeting of the West Virginia Academy of Science in  
Joint Session

with

The Kanawha Valley Section of the American Chemical Society at  
Charleston, West Virginia, April 26-27, 1929.

Friday, April 26, 1929.

Rotary Room, John L. Tilton, Presiding.

- 1:00 P. M.—Greeting, C. L. Voess, President of The Kanawha Valley Section of the American Chemical Society.  
Reply, John L. Tilton, President of the West Virginia Academy of Science.  
Business of the Academy: (This is an open session and all are invited to attend).  
Reports of Officers.  
Report of Executive Committee.  
Report of Standing Committees.  
Election of Members.  
Appointment of Special Committees.  
Other Business.
- 1.30.—President's Address, Rotary Room, "The Trend of Geologic Thought." 25 minutes.
- 2:15.—Meetings by Sections.

## PAPERS

## Biology

(Botany, Zoology, Physiology, Medicine, Agriculture).

S. Benton Talbott, Chairman, Room 607.

1. Thomas W. Skuce: Some Problems of Natural and Artificial Reforestation Arising from Our Cut-over Timberlands. 10 minutes.
2. C. L. Newcombe: The Allegheny Cliff Rat. 10 minutes.
3. Frank C. Gilbert: A Preliminary Report on the Slime Moulds of West Virginia. 10 minutes.
4. B. R. Weimer: Modern Trends in the Teaching of Biology. 10 min.
5. W. M. Sharp: The Starling in West Virginia. 10 min.
6. W. I. Utterback: Animal Phylogeny. 15 min.
7. Hazel C. Cameron: Weight Changes of the Suprarenal Gland in Vitamin A. Deficiency. 10 min.

## Chemistry

(Chemistry, Chemical Engineering, Pharmacy).

Carl G. Campbell, Chairman, Rotary Room.

1. L. P. Hansen: Color Reactions of Cyclic Aromatic, Cyclic Aliphatic and Straight Chain Aliphatic Aldehydes and Ketones. 20 min.
2. L. P. Hansen: Quantitative Studies on Some Errors Involved in the Munson-Walker Method. 20 min.
3. E. B. Kester: Arsenic, a Friend and Enemy of Man. 20 min.
4. W. C. Weltman: The Importance of Analytical Technique. 20 min.
5. J. S. Klumpp: Chemistry as an Aid in Medical Diagnosis. 20 min.
6. W. H. Walker: Solubility of Hydrochinone in Various Liquids. 20 min.
7. F. J. Kauffman: A Comparison of German and American Industrial Processes. 20 min.
8. W. H. Cornetet: Vitalization of High School Chemistry. 20 min.
9. E. P. Phelps: Encouraging the Slower Student. 20 min.

## Geology and Mining

(Geology, Coal and Oil Engineering, Road Commission, Building Material).

C. E. Lawall, Chairman, Assembly Room.

Symposium: The Monongahela Series.

1. Wilbur Stout: The Monongahela Series of Ohio. 20 min.
2. David B. Reger: The Monongahela Series of West Virginia. 20 min.
3. George H. Ashley: The Monongahela Series of Pennsylvania. 20 min.
4. Reinhardt Thiessen: The Microscopic Structure of the Coals of the Monongahela Series. 20 min.

5. Earl L. Core: Stratigraphy of the Dunkard Series near Core, West Virginia, illustrated by lantern slides. 10 min.
6. Frank Parris: The Pottsville of Ohio, illustrated by lantern slides. 10 min.
7. Andrew Price: Trilobites from Chert Beds of Pocahontas County, West Virginia. 10 min.
8. W. A. Koehler: Some Aspects of the Pottery Industry of West Virginia. 15 min.
9. Charles E. Lawall: Mining Education in West Virginia High Schools. 10 min.

#### Mathematics and Physics

(Mathematics, Astronomy, Physics, Mechanical Engineering, Electrical Engineering).

Robert C. Colwell, Chairman, Room 609.

1. J. Eiesland: On the General Rule  $V \frac{n-1}{n-1}$  in Sn. The  $V \frac{4}{4}$  in S<sub>5</sub>. 15 min.
2. H. A. Davis: Non-involutorial Transformations Belonging to a Linear Complex. 15 min.
3. C. N. Reynolds, Jr.: On Polyhedra and Polytopes (Abstract). 10 min.
4. R. B. Mathews: Certain Groups of Order 8p with Three Generators. By title.
5. George B. Welch: A "Patch Theory" of Photoelectric Fatigue. 10 min.
6. O. Rex Ford: Change of Shear Modulus with Temperature. 10 min.
7. R. P. Davis: Some Technical Features of the New Charleston Bridge. 30 min.
8. R. C. Colwell, R. G. Owens, W. M. Dove: The Effect of Weather Conditions on Radio Reception. 10 min.
9. Leo G. Raub. Some Effects of Color and Illumination.

#### Social Sciences

John E. Winter, Chairman, Room 129.

(Philosophy, Psychology, Education, Economics, Sociology, History).

1. R. E. Saleski: The Psychological Study of Language. 15 min.
2. J. B. Shouse: Comparative Results of Different Methods of Scoring Test Papers. 15 min.
3. H. T. McKinney: Our Evolving Social Conception of School. 15 min.
4. John E. Winter: Relation of Mind and Body. 15 min.
5. R. E. McConnell: The Origin of Mental Tests.
6. M. Swearingen: Some Economic Aspects of Southern Reconstruction. 6:30 P. M. Dinner, Rotary Room, Hotel Kanawha, \$1.50. (No speeches).

## EVENING PROGRAM

8:00 P. M.—Rotary Room, C. L. Voress presiding.

Introduction of winner of the essay contest, by John L. Tilton.

Reading of the Prize Essay: Out of Doors Where I Live—Award of Prize, by John L. Tilton.

(The winner of the prize was Miss Dorothy Gwinn of the Elkins High School, Elkins, West Virginia. Owing to the absence of Miss Gwinn, the prize essay was read by Mr. Fred E. Brooks of French Creek. The check for \$25.00 was then given by President Tilton to Dean Albert of Davis and Elkins College with instructions to present it to Miss Gwinn as the award of the Academy in recognition of the superior merits of her essay).

## Address

(Provided by the Kanawha Valley Section of the American Chemical Society).

Dr. Roger Adams, University of Illinois.

Recent Advances of Synthetic Organic Chemistry in Medicine, (Illustrated by lantern slides).

Informal Reception (following the address), Rotary Room.

## Saturday, April 27

7:30 A. M.—Breakfast and Business Meeting of the "West Virginia Chemistry Teachers' Association," Friend E. Clark presiding, Rotary Room, Hotel Kanawha, \$.75.

Address, Rotary Room, Dr. Neil E. Gordon, Johns Hopkins University. The Exceptional Student.

9:00 A. M.—Rotary Room, John L. Tilton presiding.

Remaining Papers.

Business: Unfinished Business. New Business.

Reports of Committees: Auditing Committee, Committee on Resolutions, Committee on Nominations.

Excursions to industrial plants and to other places, under the management of Mr. S. P. Puffer, Secretary of the Chamber of Commerce, and Mr. W. T. Slicer, Southern West Virginia Automobile Club.

Adjournment.

## Saturday Morning

At 9 o'clock the Academy was called to order by President Tilton. The report of the Treasurer was read and approved. The chairman of the Auditing Committee reported that the records of the treasurer were found satisfactory, which report was accepted.

**Report of the Treasurer**

Cash in bank reported May 18, 1928.....	\$321.58
Receipts for Current Year:	
Two checks of \$22.50 each, Refund of A. A. A. S.....	45.00
From dues and initiations.....	46.00
	<hr/>
	\$412.58
Disbursements:	
Checks (Nos 12 to 25 inclusive) for itemized expenses..	\$125.43
Prize for Essay.....	25.00
	<hr/>
	\$150.43
Balance in bank now.....	262.15
	<hr/>
	\$412.58

Respectfully submitted,

H. T. McKINNEY, Treasurer.

Examined and Approved, April 26, 1929.

(Signed) CHAS. E. ALBERT,

EARL C. H. DAVIES,

## Auditing Committee.

The special committee appointed to consider the continuance of the plan for a High School Prize Essay then gave its report, which reads as follows:

"The committee recommends: 1st, that the present plan for offering a \$25.00 prize for the best essay submitted by a high school student be continued. It is suggested by the committee, however, that the subject of the essay be more specific and that the contestants be allowed to choose between such subjects as 'Birds,' 'Flowers,' 'Trees,' 'Rocks,' etc. The subjects from which the choice is made are to be selected by the Executive Committee of the Academy and changed each year, if thought expedient.

2nd, that the loan fund established by the Academy be discontinued and a scholarship fund started. It is recommended that as soon as this scholarship fund is sufficient in amount to justify offering a scholarship of \$200.00 a year for two years to a promising scientific student to enable said student to pursue graduate work in a recognized graduate school, the Executive Committee of the Academy be empowered to offer such a scholarship. It is recommended that in choosing the recipient of the scholarship each degree granting institution of West Virginia be allowed to certify to one candidate selected from the senior class of the institution. From among the various candidates submitted the Executive Committee of the Academy is empowered to choose, in

whatever way is thought desirable, the student who is to receive the scholarship."

Committee:

ALBERT C. WORKMAN,  
D. B. REGER,  
MAURICE BROOKS,  
JOHN EIESLAND,  
J. E. WINTER.

The Academy voted to accept the first part of the report and to place the second part proposing the accumulation of a scholarship fund on file.

The membership committee presented the names of ten candidates for membership in the Academy and the secretary was instructed to cast the ballot for the election of these candidates. The list is as follows:

Miss Berenice Collins, 1215 Quarrier St., Charleston, W. Va.  
Miss Hazel Cameron, Expt. Sta., Morgantown, W. Va.  
Miss Laura B. Moore, Parkersburg, W. Va.  
Lewis Fest, Teacher of Chemistry and Physics, Elkins High School.  
Bayard Green, Teacher of Biology, Elkins High School.  
F. D. Galbraith, Chemistry, Potomac State, Keyser.  
M. Swearingen, Marshall College, Huntington.  
R. E. McConnell, Marshall College, Huntington.  
R. C. Woods, Marshall College, Huntington.  
Frank S. White, Fairmont Normal, Fairmont.

A motion was made to restrict the requirements for membership and after considerable discussion a substitute motion was passed providing that the original motion be laid on the table until some subsequent meeting of the Academy.

D. B. Reger, Chairman of the Committee on Resolutions, then gave the report of that committee, which is as follows:

Resolved: That the West Virginia Academy of Science in its sixth annual meeting extends to the Kanawha Valley Section of the American Chemical Society thanks for its friendly cooperation in securing a speaker for the evening program; to the Rotary Club of Charleston for its courteous interest; to the Southern West Virginia Automobile Club and the Charleston Chamber of Commerce for the arrangement of

sightseeing tours; and to the management of the Hotel Kanawha for the use of assembly rooms.

(Signed) DAVID B. REGER, Chairman,  
H. F. ROGERS,  
JOHN EIESLAND.

The reports of the chairmen of the various sections were as follows:

S. Benton Talbott, Chairman of the Biology Section, reported an attendance of thirty. B. R. Weimer was elected chairman for the ensuing year.

Carl G. Campbell, Chairman of the Chemistry Section, reported an attendance of twenty-five. Earl C. H. Davies was elected chairman.

C. E. Lawall, Chairman of the Geology and Mining Section, reported an attendance of twenty-five. Mr. Lawall was reelected chairman of the section.

R. C. Colwell, Chairman of the Physics and Mathematics Section, reported an attendance of fourteen. There was no election of a chairman for the coming year.

J. E. Winter, Chairman of the Section of Social Sciences, reported an attendance of thirteen. Mr. Winter was reelected chairman of this section.

The Chairman of the Committee on Nominations gave the following report:

The committee reports and makes the following recommendations on nominations:

For President, H. F. Rogers.

For Vice-President, A. B. Brooks.

For Secretary, P. D. Strausbaugh.

For Treasurer, H. T. McKinney.

For Curator, John E. Winter.

(Signed) B. R. WEIMER,  
C. G. CAMPBELL.  
ANDREW PRICE.

The secretary was instructed to cast the ballot of the Academy for those nominated by the committee.

The Academy then gave President Tilton a rising vote of thanks for the efficient and faithful service rendered by him during his term of office.

Following the final announcements by the president concerning the excursions planned as a part of the general program of the Academy, the meeting was adjourned.

P. D. STRAUSBAUGH, Secretary.

### SPECIAL ADDRESSES

GREETING: by C. L. VORESS,

President of the Kanawha Valley Section of the American Chemical Society.

On behalf of the Kanawha Valley Section of the American Chemical Society I wish to extend a cordial welcome to the members of the West Virginia Academy of Science. I deem it a great privilege. Your officers have generously invited the membership of our section to attend all your meetings and particularly to participate this evening. For this we thank you and promise you that we will do all in our power to help make your meetings successful and your stay in Charleston pleasant.

It is particularly fitting that you should come to Charleston at this time. Your group is composed of scientists in the fields of geology, physiology, psychology, engineering, mathematics, chemistry, and many others. Your membership includes many of the leading scientists of West Virginia. These men are awake to the need of balancing fundamental research against applied science.

West Virginia is blessed with natural resources all out of proportion to those of most of her sister states. The coal, oil, natural gas, and timber enterprises have flourished for many years, but it is only in the last five years that attention has been turned to her abundance of raw material for the chemical industry. The section of over 150 chemists which I represent was made possible by this chemical development.

This new development is bringing to the scientists of this state three distinct problems.

First: Applied technical development in any community always requires that the scientific courses offered by the schools to our youth be expanded, made more thorough and be given to greater numbers. Scientific education cannot be limited to a few specializing in chemistry, geology, or engineering. The lawyer, for instance, has a new type practice developing. The banker must widen his vision to properly serve this new field. The business man has a new field of endeavor. Unless we, as West Virginians, grow with our new developments, our youth must go outside the state for special training or trained youth of other states must come to us.

Second: Fundamental research must keep pace with applied science. More and varied fundamental research by West Virginians directly applied to the raw materials of West Virginia is a crying need. We are permitting much of the fundamental research on our raw materials to be conducted outside the state, and as a consequence the applied research is also done outside the state. The resulting developments are then most naturally financed with money from other states.

Third: We must give our activities wider publicity so that the great mass of people of this state may know the accomplishments and lend sympathetic ears against adverse legislation. Not only must our legislature sponsor wisely true fundamental research and the training of our youth for scientific endeavor, but adverse legislation must not be passed to stifle and throttle our new industries based on applied science.

Again I say that it is indeed a pleasure to welcome you to Charleston.

RECENT ADVANCES OF SYNTHETIC ORGANIC  
CHEMISTRY IN MEDICINE

By ROGER ADAMS,  
Professor of Chemistry, University of Illinois.

## (Abstract)

The scope of the subject "Recent Advances of Synthetic Organic Chemistry in Medicine" is so extraordinarily broad that it is absolutely necessary to limit a brief discussion such as this, to selected fields which are of more general interest than the others. The goal of an individual working in the field of synthetic drugs is to discover a substance which will have a highly specific effect upon the cause of the disease, whether bacterial or otherwise, and a minimum effect upon the human system. It may be stated that no ideal substance for any purpose has been found. Each problem resolves itself into finding as favorable a combination of properties as possible. With such conditions existing, there always will remain the stimulation to the new investigator to improve upon the products of his predecessor.

A question which is frequently asked, particularly by laymen is—how does one go about discovering a synthetic drug? If discoveries are traced back, it is found that there are actually not more than two important general methods of attack.

The first depends upon the information obtained from a chemical knowledge of natural products made possible by the rapid progress in organic chemistry during the past fifty years. For centuries many of the most useful remedies in medical science have been known. They are found in Nature, particularly in herbs, leaves, and roots, and were discovered and used as such long years ago by uncivilized people. Information about them has been handed down from generation to generation. Modern chemistry has lent its aid, to be sure, with the results that the active principles are now at the call of the physician. Among these compounds are morphine, quinine, atropine, and the like. The chemist has been able to go still further, however, and in many instances to determine the complete structure or at least to get much information about the structure of many of the molecules of these physiologically active natural products. This information has led to many researches, not only on the study of the chemical modifications of such natural molecules, but also on the study of synthetic molecules containing merely that portion of the natural molecule which appears to be essential for the physiological activity. Even with the intensive development of synthetic drugs, the large majority of these natural products still hold their own.

The second general method of procedure has its dependence on the observation of the pharmacological or bacteriological action of certain

very simple organic or inorganic compounds, most of which, in themselves, cannot be used in medical treatment, because of toxicity to the human system in one way or another. With such information, in many cases in a more or less empirical way, compounds have been built up which have the proper combination of properties for clinical use.

Another factor which cannot be overlooked or discounted is the part good luck plays in some discoveries. A few of our outstanding medicinals, such as antipyrine or saccharine, have been discovered merely by chance. If one of Remsen's students had not, by chance, placed his pencil point in a product and then in his mouth, saccharine and its sweetness might never have been discovered.

A number of important researches have had as their object the synthesis of molecules identical with the natural products. Though always of highly scientific interest, the processes have proved, in a few cases, to be of economic interest also. Among the highly complicated molecules which have been synthesized are cocaine, quinine, atropin, adrenalin, ephedrin, and thyroxin. The procedures for the first three have been a contribution to science only, but the procedures for the latter three, are being used at the present time for the production of material sold in competition with the natural. Synthetic thyroxin can undoubtedly be made at a price which will allow it to supplant the natural product.

Synthetic drugs obtained by slightly modifying the molecules of natural substances have not resulted in as many products of value as might be anticipated. Atropine extracted from Belladonna has long been one of the standard mydriatics and narcotics. This complicated tertiary amine has been converted into a variety of salts. Morphine, one of the physicians' most important tools, has been treated with various reagents so as to modify its functional groups. Acetyl morphine and other derivatives have been produced. Quinine, a valuable specific for malaria and important antipyretic has been studied chemically and converted particularly into numerous esters. The derivatives of these three drugs have in practically all cases had analogous physiological action to the respective mother substances and no compounds of outstanding importance with possibly a single exception have been developed.

The synthetic drugs discovered by synthesizing products containing merely the essential groupings in the molecules of the natural occurring compounds, has brought more lucrative results. The outstanding example of such a development is found in the field of synthetic local anesthetics. Products have been discovered which have essentially supplanted cocaine, formerly a highly important drug. A careful study of cocaine revealed the grouping in the molecule which was essential to its anesthetic action, and synthesis of compounds containing such a grouping resulted in the discovery of procaine (novo-

caine), one of the most widely used of the synthetic drugs. Procaine is non-habitforming, has a low toxicity, a high degree of stability, and many other advantages over the natural product. Procaine does not cause as rapid anesthesia as cocaine nor is it as effective for mucous membrane work. These are minor disadvantages, however. A field as important as the local anesthetics, has resulted during the last ten years in intensive study resulting in the synthesis of a number of local anesthetics which have appeared on the market. The more important are apothecin, psicaine, butyn, tutocaine, and supracaine. Butyn has the property of anesthetizing the mucous membrane and has essentially replaced cocaine for this purpose. It has stability, quick action, more lasting effect, and other properties distinctly superior to cocaine. Most of these new products are the results of attempts to combine the valuable properties of butyn and procaine in the same molecule, at the same time obtaining a low toxicity. It can hardly be said, however, that such a goal has, as yet, been reached. In practically all of these compounds a greater anesthetic action is observed than in procaine, but this advantage is offset by the greater toxicity and in no case is the mucous membrane anesthesia as great as that of butyn.

An important part of the quinine molecule is the quinoline nucleus. As a consequence many quinoline derivatives have been studied and tested pharmacologically. Plasmoquine has been discovered which in many cases is reported as superior to quinine. During these investigations it was found by mere chance that phenyl cinchoninic acid and homologues were shown to be excellent uric acid eliminants and are now recognized as among the most important remedies known to the medical profession.

The developments evolved from a pharmacological and bacteriological knowledge of some of the simple compounds in inorganic and organic chemistry touch almost every kind of medicinal and have led to many new products for which there was no previous substitute. The soporifics can be traced back to the observation of the narcotic effect of ethyl alcohol after its stimulating effect has subsided. Compounds containing an ethyl group were naturally studied. Over a period of years ethyl ether, urethane, chloral, sulfonal, urea derivatives and finally barbiturates were developed. The last group is of extreme importance.

Ever since Koch made the discovery that gold cyanide was toxic in very, very dilute solutions toward the tuberculosis organism in vitro, gold compounds of every type, especially organic gold compounds, have been investigated. It is true that nothing has been discovered that solves the problem but many prominent physicians are still optimistic that eventually an effective gold compound for treatment of tuberculosis will be found.

It is hardly necessary to mention the important development among

organic arsenic compounds. Ehrlich, acting upon the observations that white arsenic was a very active toxic toward spirocetes, spread his investigations to every type of organic arsenic compound, until, after the study of literally hundreds of compounds he was rewarded by the discovery of arsphenamine and neoarsphenamine, which are indispensable drugs at the present time and for which absolutely nothing comparable was available previously.

The use of mercury salts as diuretics has been known for a long time. More and more organic mercury compounds of low toxicity are coming to the front and appear to be far superior to older remedies.

Antiseptics among organic compounds have perhaps been sought more than any other type of medicinal. The rewards have been great—metaphen and mercurochrome 220 among the organic mercury compounds, acriflavine among the acridines, hexyl resorcinol among the phenols, pyridium among the pyridine compounds.

Pyramidon and antipyrine, very important analgesics, ammonium ortho-iodoxy benzoate, which shows some promise for treatment of arthritis, carbon tetrachloride for hookworm disease represent important examples of useful drugs discovered merely by chance during the testing of these chemicals for other purposes.

To summarize after this brief review of the more important synthetic drugs, it is obvious that the whole development is still in a comparatively empirical stage. There are no fundamental laws on the relation of pharmacological action to chemical constitution and it is, therefore necessary for the chemist in this field to use in many cases an apparently minor observation or to employ the information obtained from a natural product as a basis for his investigation and develop his experiments more or less empirically in the hope of discovering some useful drug.

## THE EXCEPTIONAL STUDENT

By NEIL E. GORDON,  
Professor of Chemistry, Johns Hopkins University.

## (Abstract)

In the past American educational effort has been centered chiefly on the student of average or poorer capabilities. There is no complaint about this but science and civilization have now reached a stage of development where the solution of problems is becoming increasingly difficult. For progress we must look more and more to the exceptional man and we must devote more attention to developing the abilities of his forerunner, the more highly talented student.

It has been said that the highly endowed will take care of themselves. There is a persistent theory among many that genius "will out." The fact that talent does sometimes surmount unusual obstacles may well be the exception rather than the rule, however, there is no reason to suppose that genius will profit less by favorable conditions than will mediocrity. It rests with us as educators, to give special attention to the highly endowed. This is especially true in such a science as chemistry where real progress can only be made by creative minds.

The new National Fellowship Plan just launched at The Johns Hopkins University is for the purpose of finding what can be done to eliminate the waste of intelligence involved in present educational practices, without abandoning the democratic ideal of education so firmly implanted in American thought. We do not intend to encourage any intellectual snobbery, but we do intend to work out a philosophy of chemical education which shall lay equal emphasis upon the **selection** and **training** of men.

In the selection of men to be trained under the new plan we have taken into consideration those qualifications which experience has demonstrated are essential to leadership. They are:

- |                                 |                                   |
|---------------------------------|-----------------------------------|
| (1) Health (7.8)                | (6) Faculty of observation (10.1) |
| (2) Creative ability (13.7)     | (7) Executive ability (8.9)       |
| (3) Book ability (7.3)          | (8) Conduct (7.8)                 |
| (4) Intellectual honesty (11.0) | (9) Personality (9.2)             |
| (5) Perseverance (8.9)          | (10) College standing (15.3)      |

The marks to the right of these qualifications are the average values assigned by directors of some of the outstanding chemical companies, which are constantly looking for exceptional men. It may be a surprise to some to note that scholarship is estimated to count only 15.3 toward the probability of the student's success. The exceptional students for whom we are looking are not only the so-called intelligent students but those who likewise rank high in other qualifications.

The nine boys who have thus far won these fellowships in their respective states are:

Robert D. Stiehler, Rensselaer Polytechnic Institute, N. Y.  
Kenneth E. Glidden, University of New Hampshire, N. H.  
John R. Ruhoff, University of Wisconsin, Madison, Wis.  
Willard E. Bleick, Stevens Institute of Technology, N. J.  
Robert W. Cairns, Oberlin College, Oberlin, Ohio.  
Maurice E. Krahl, DePauw University, Greencastle, Ind.  
Theodore E. Field, Bates College, Lewiston, Me.  
Michael S. Ebert, Lehigh University, Bethlehem, Pa.  
Paul P. Sutton, The Johns Hopkins University, Baltimore, Md.

These boys are to enter the university this coming fall when special attention will be given to their training. If necessary reorganization of courses will be made to insure that the training offered is fitted for these selected students. "Habit-forming" education will be reduced to a minimum while the scope for original thinking will be enlarged to a maximum, in order to cherish that creative ability which is so highly important and on which progress, especially in chemistry, depends. The courses will possess more thoroughness, more depth, more quantity, in recognition of the fact that average student work is too "thin" for these selected students. We shall aim to avoid the herding idea and deal with the individual.

The Address by the President of the Academy:

## THE TREND OF GEOLOGIC THOUGHT

By JOHN L. TILTON,  
Professor of Geology, West Virginia University.

(Abstract)

Conceptions of the past have been modified by a study of nature, but in it all are law and order—an Organizer. Geology utilizes all of the sciences in its study of the processes of nature. Beginning with the Planetesimal Hypothesis it seeks to trace the events of the dim past, then by means of the position of beds in their relation one to another and by means of the remains of ancient forms of life both plant and animal, it traces the sequence of events from that distant past toward the present, both in the physical conditions and in the varying life of the past, thereby revealing a great lapse of time. It also studies the resources of the strata, that the resources may be utilized in an economic manner, that a foundation may be laid for greater prosperity in both the immediate future and in the distant future.

\* \* \* \* \*

In the preparation of this paper I have in mind not so much the audience here before me, many of whom are fully qualified to speak on the subject announced, but I have in mind that great concourse of people, the citizens of our beloved state, who see the wonders of nature around them and revel in the beauty, but in many cases seem unaware of sequence of events that have led up to the present, and seem unaware of the great lapse of time of which there is evidence on every hand.

Back in the distant past we find the conception of a nature peopled with numerous gods, each a ruler in his own realm, or the guardian of a tribe that worshipped him. This ancient idea of gods and demons has not yet completely vanished, for in a large part of the world that we call uncivilized many different gods beneficent and gods harmful are still worshipped. Where the little-understood forces of nature are thought to be the agents of despotic deities law and order are not recognized in the physical universe. Among the ancient peoples there was one nation whose conception of deity grew into a recognition of the presence of one true God, supreme, all-powerful, all-wise, just, and the ruler over all nature. Here is a recognition of a relation between cause and effect, of constancy in nature, of the presence of law and order. Thus, though they did little to develop science, they, as they looked out upon nature, recognized centuries ago from their restricted viewpoint, the grandest thought of all, a thought which all science in these latter days is obliged to recognize: In all the complexity of the heavens, in all the processes on the land and in the sea, in all life, both

plant and animal, law and order prevail. In that law and order organization is only possible where there is an organizer. That organizer we call God. Only as there is such an organizer is science possible. This ancient concept is the early gift of the Hebrew race, perpetuated in Christendom, and amplified in a wonderful way in modern science. Therein we recognize law and order everywhere, seek to learn intricate details, and more and more in the infinite details see evidence of omniscience. With the ancients, but with expanded view, we humbly bow before the Ruler of the Universe.

Geology seeks to learn all about the earth of the present and of the past, and of the varied inhabitants in the different ages. Thus it makes use of all the sciences in their relation to the earth. From Astronomy we learn that the heavens is not a solid dome stretched above the earth, but an infinitude of space in which, at distances almost inconceivable, are star systems moving in an orderly array. We learn that the earth is one of several planets rotating on their axes and revolving around the sun, that the moon is a satellite of the earth, with relations to the earth like those of the satellites of several other planets. It was after the discovery of the laws of gravitation that thought was turned to trace the origin of the earth, and, among other hypotheses, the Laplacean Hypothesis was developed based on relations as they were then understood. This hypothesis was soon found to be faulty in certain particulars, but the sensible course was followed in that the hypothesis was allowed to serve its purpose till something better could be developed. Strange as it may seem it was geology that furnished the basis for further criticism, and led to further critical study of the Laplacean Hypothesis. It has been proved that the earth is not a molten (liquid) mass with a crust like the skin of a withered apple in which the wrinkles stand for mountain chains. It is found that way back in the history of the earth there were times of widespread glaciation, comparable to that of the last or Pleistocene glaciation, and that therefore in that long history the earth has not been cooling from a hot liquid condition to its present condition, but that even in those distant ages, there was a climate much like the climate of the present, a condition in the past for which the Laplacean Hypothesis cannot account. The study of the mechanics of the formation of rings under the Laplacean Hypothesis, followed by the development of spheres from the rings, not only met with difficulties, but the mechanics of the process required a distribution of mass and momenta that does not exist in the solar system. Thus the Laplacean Hypothesis has had to yield to the Planetesimal Hypothesis, devised to fit the facts that are known both in Astronomy and in Geology. In this hypothesis instead of rings we have nuclear masses shot out by the sun toward a passing star. Into these central bolts as nuclei were gradually gathered much of the material, or planetesimals, that had been scattered out as the bolts were thrown

out from the sun. As the bulk of each nucleus grew it became warmed by compression, and after a while some of them, as the earth, but not the moon, became large enough to hold escaping gas and thus accumulate an atmosphere, and then a sea. With an atmosphere and an ocean came conditions suited to life, and with them also came erosion of land forms, in processes that have been operative ever since, and now form so attractive a study as we watch the carving of the land and the journey of the products toward the sea.

From such a background as the Planetesimal Hypothesis gives us we can look without surprise at the evidence of varying climatic conditions way back in the oldest rocks that are recognized, and find that the same processes were operative in those times that are operative now. The iron of the great beds of iron ore such as are now in the Lake Superior region, was weathered out, transported to bogs, precipitated by bacterial action, and later concentrated into richer beds, by processes requiring great lapse of time, in which ancient landscapes were developed that now disappear beneath the overlap of other later but ancient beds.

Along with varying action of an atmosphere, at times depleted of its carbon dioxide, and at times enriched as climatic conditions changed from those associated with widely extended glaciers to other conditions in which corals thrived within the Arctic circle, a new factor appears on the horizon of thought, in the variation of heat given out by the sun. The so-called Solar Constant of heat is found to vary somewhat. As to how much that variation may really prove to be, we wait with interest for the accumulation of data.

The character of those surface changes in the rocks is solved by the application of chemistry. In places some of the elements oxidize, some unite with carbon dioxide, some take water into their molecular compositions and some go into solution. Under suitable conditions of pressure and temperature, as deep in the earth, these processes are reversed. The oxides lose oxygen, the carbonates lose carbon dioxide, and the hydrated minerals lose water.

Such changes are further studied by the application of the microscope in the effect upon polarized light passed through thin sections of rock. Thus by the study of volcanic rock and of other rocks from crystalline areas as well as by the study of rocks from weathered products deposited in beds, the composition of minerals present can be recognized and changes determined to which the rocks have been subjected. The trend of geologic thought in this direction leads to long-continued accumulation of useful and valuable data. Microscopic methods are also used in metallurgy and in manufacturing processes, with a wide field open for future usefulness.

The study of rocks has led to the recognition of changes that have taken place even deep within the earth. Such knowledge is further

extended by the study of vibrations from earthquake areas in which the locations of earthquake centers are ascertained. From the data accumulated the velocity of transmission deep within the earth has been worked out, and from the character of the wave transmitted the solid condition of the earth has been ascertained, unless it be for a relatively small volume near the center of the earth. Such methods applied during the war helped locate submarines and concealed batteries. Now the methods developed in the war are used to determine rapidly the various depths of the ocean, so that in a few years we shall know more definitely of the actual shape of the bottom of the deep portions of the ocean, which in turn will affect our conception of the relation of continent to ocean bed. Such methods used in the study of earthquakes are also now used in the study of structure in its relation to the accumulation of oil and gas.

Along with the study of the interior of the earth through vibrations has come a study of the value of gravity in numerous places on both land and sea, leading to the conception that at a depth of sixty to an hundred miles beneath the surface the various columns of rock, so different at the surface, balance each other. The mass beneath a mountain stands in approximate equilibrium with the mass beneath neighboring plains. How this equilibrium can be maintained when the processes of erosion are constantly at work removing mountains, has led to the recognition of movements that must take place under the mountains and plains in the semiplastic material above that depth of sixty or a hundred miles to maintain the approximate equilibrium. From the Planetesimal Hypothesis we get a conception of the origin of ocean beds and of continental platforms, topographic features of the first order; and from isostasy we get a conception of the movement of deep-seated material in maintaining equilibrium beneath topographic features of the second order. The times of movements are related to the times of mountain building, with intervening times for the development of peneplains. Conceptions of processes in mountain folding and faulting as great synclinal accumulations of sediment are squeezed into mountain masses are supplemented by this work under isostasy.

What the real source is of the forces that cause great masses of the earth to jam together, to rise, to fall and to bend, is but little understood. We may recognize the effects of loss of heat in radio activity, and judge that the earth is gradually shrinking, and we may study the mechanics involved in mountain building. Beyond this, thought is turned to further insight into the great causes that have elevated mountain masses, that have placed great areas repeatedly beneath the level of the ocean, and that at other times have made those same areas parts of the dry land.

From the study of the distribution of life along the shores and far out into deep waters there is already developed an extensive knowledge

of fauna and flora of the ocean, leading to the recognition of the shallow water condition of fossil horizons, and of rare occurrence of deep sea faunas.

In the study of sedimentation even the laboratory methods of Bacteriology are brought into use revealing a wide realm of action by bacteria and other lowly forms of plant life in the formation of limestone, of sulphides, of beds of iron and of coal. They are found to be an important agent not only in bays but even in abysmal depths; not only in the soil, but deep beneath the surface of the land.

From the study of modern peat beds and from the study of coal and of associated beds the character of the plants whose products form the coal has been worked out, and the manner of bacterial action to produce the maceration of that material. From the flattened stems the amount of mashing under pressure is ascertained, and under the microscope even the microscopic details of the cell structure of the plants are visible, all revealing forest types far different from the forest types of the present. Further work is revealing a wealth of products stored away in those old coal swamps from trees that grew on the old landscapes now visible here and there beneath exposed edges of strata that have accumulated to thousands of feet in thickness. We are just beginning to utilize the biproducts from those ancient plants, and to dream of conservation, that such great wealth of material may not be wasted.

Farther back in the oldest rocks we see streaks and beds of graphite, and recognize the remains of still more ancient beds of plants formed into seams of coal and then later reduced to graphite. In beds laid down later than our beds of coal we see beds of lignite from plants of a different type than those from which our coal is formed, and in the present see conditions around peat bogs and tamarack swamps, till we think there is a fair record preserved of plant life from the present back through the Paleozoic rocks, and beyond that, evidence of abundant plant life of less certain character revealed in the graphite found even in the very oldest stratified rocks.

So, too, in the animal life the types of the various forms that lived are studied and the changes found used to help trace the beds from one place to another. Corals that lived when various early beds were laid down can be compared with corals found in later beds and with corals of the present. Shelled forms found in the various early beds can be compared with those found in later beds and peculiarities noted used to help decipher the relation of isolated patches of strata, and the relation of extensive sheets exposed only here and there. This is particularly true of a group of shelled forms known as brachiopods, the variations in which group serve as markers of various paleozoic beds. These may serve to illustrate the many groups of forms that now serve to indicate marine beds of different ages, till now the extents of various

seas that were formerly wide spread over the continent are mapped, the sea ways along which these inland seas were connected with the oceans ascertained, whether with the Atlantic, the Gulf, the Pacific or the Arctic, the sources recognized from which some of the elements of the faunas were derived, and the changes of form that occurred in the course of ages ascertained by comparison of organic forms that are found.

A study of minute forms has found special application in determining the position of beds in their relation to beds that are rich in oil.

Thus by the study of the position of strata and by a study of their content various beds are traced, some over wide areas, and others to narrower confines, till the major relations are marked out; and work now progresses toward minor details.

So, too, in the rocks old land surfaces have been detected, surfaces that in former ages made the hills and valleys of those times. Among the many variations marking old landscapes we note but two. One is in our own state near Elkins where the sign by the roadside marks the location of old logs now preserved in sandstone, the location of the "David B. Reger Fossil Tree Park." The other is amid the Great Plains, where in the successive beds the remains of animals are preserved that lived there when those beds were laid down. Thus we know of ancient bogs with great reptiles, and of later dry ground with horses, camels, rhinoceroses and oreodonts; and later still of the home of elephants, mastodons, tapirs and peccaries.

By arranging the strata in the order of their overlap and using the fossils to help connect the strata together we thus have a double record: one of the succession of the strata, and the other of such life as lived when the beds were laid down; and by a wide comparison of such data from various parts of the earth we gain a knowledge of migration, and of changes that in the course of time occurred in the groups of plants and animals.

Then, too, where the strata are in folds the various beds are seen one after another to disappear downward beneath the surface, and to appear again in their proper order farther on, as marked by the character of the strata and of the fossil content; and where the strata are broken and one part slipped over another the relation has been studied out and the beds ascertained that are involved in such breaks or faults. Major relations are already worked out, but minor variations are constantly looked for especially in the search for oil and gas.

From the study of such relations the strata of West Virginia are arranged in a stratigraphic column:

## GEOLOGICAL COLUMN OF WEST VIRGINIA\*

SYSTEM	SERIES	SUBDIVISIONS	OIL SANDS	Thickness Feet	Total Feet	
Pleistocene		Carmichaels Clay				
Permian	Dunkard			1000-1180	1180	
Pennsylvanian	Monongahela		Carroll	300- 410	1590	
			Minshall			
	Conemaugh		Murphy			
			Moundsville (Saltsburg)			
			First Cow Run (Little Dunkard)			
			Buffalo (Big Dunkard)		500- 630	2220
			Burning Springs			
		Allegheny		Lower Freeport	250- 330	2550
	Mississippian	Pottsville	Kanawha			
			Homewood	Second Cow Run		
			Upper Connoquessing and Lower Connoquessing		100-2100	4650
			New River			
			Sharon		150-1030	5680
		Pocahontas	Cairo	0- 720	6400	
		Mauch Chunk	Maxton, Dawson			
Pencil Cave			100-3400	8675		
		Greenbrier	Tennesseian	Big Lime	60-1800	9432
		Pocono	Maccrady			
Logan, Burgoon	Keener, Beckett					
Devonian		Waverlian	Big Injun			
		Catskill (Hampshire)	Squaw (Weir)	450-1995	11427	
			Berea			
			Gantz			
			Fifty-foot			
			Thirty-foot			
			Stray			
			Gordon			
			Fourth			
			Fifth (McDonald)			
			Sixth (Bayard)			
		Chemung	Elizabeth	600-3200	14627	
			Jennings)	Warren		
	Tiona					
		Speechley				
		Benson				
		Kane	2115	16742		
	Portage		1765	18567		
	Genesee		196	18703		
	Hamilton	(Romney)	1004	19707		
	Marcellus	Onondaga	330	20037		
	Oriskany		225	20267		
	Helderberg		300	20562		

\*From Chart by R. C. Tucker and John L. Tilton, based on data from the West Virginia Geological Survey.

Silurian	Salina		800	21362	
	Niagara		170	21532	
	Clinton		550	22082	
	White Medina	(Tuscarora)	200	32282	
	Red Medina	(Juniata) Richmond	200	22482	
	Gray Medina	Oswego	50- 300	22682	
Ordovician (Champlainian)	Martinsburg	Lorraine, Maysville			
		Eden, Utica			
		Collinwood			
		Upper Trenton	2300	24982	
		Lower Trenton			
	Chambersburg	Black River			
		Lowville			
		Upper Chazy	515	25497	
	(Ozarkian)	Stones River	Chazy, St. Peter	800	26297
		Beekmantown	Stonehenge	2000	28297
Conococheague			1800	30097	
Cambrian	Elbrook	Acadian	2500	32597	
	Waynesboro		1600	34197	
	Tomstown		1000	35197	
	Antietam		500	35697	
	Harpers	Taconian, Waucobian	1200	36897	
	Weverton	Loudon	550	37447	
Proterozoic	Catoctin Schist				

In the geologic column of West Virginia certain formations are thickest in the northern part of the state and certain other formations are thickest in the southern part of the state. The minimum figures give a total of 26,180 feet; the maximum figures give a total of 37,447 feet.

When such beds as are found in West Virginia were laid down the beds were in a position essentially horizontal, as seen along the seashore today, and in them were the fragments and impressions of animals and of plants that lived in those ancient days as the sediment was laid down. The position and variations in those beds and the character of the fossil content indicate a sea bordering upon an ancient land to the east of Harpers Ferry out from which ancient land the deposits varied from sand and mud near the shore to limestone in more open water, and varied along that shore from mud and sand to coarse pebbly material derived from elevated regions of crystalline rock. This immense volume of sediment, partly derived from land immediately to the east and partly from material worked along the shore by shore currents, indicate an old land surface varying in elevation in the course of time. Following the deposition these old beds were gradually crowded together, uplifted and jammed into folds. As the uplifting progressed the weathering strata were eroded and the products transported to far distant areas, at first on the west toward an inland sea north of what is

now the Gulf of Mexico, and later toward the north past what is now Lake Erie. On the east of the old continent, known as Appalachia, the material transported into the Atlantic now lies concealed in the ocean bed. The folding clearly occurred after all beds involved in the folding were laid down, which was chiefly after deposition of the lower Permian beds. The erosion of the beds, begun as the surface appeared above the level of the ocean, has continued from that day to this. During that time the weakened strata along the axes of the folds (anticlines) were gradually reduced exposing deeper beds of various resistances. Where the ancient muds, now shale, were brought to light erosion developed the great shale valleys. Where resistant rock was exposed such rock became the mountains left between these valleys.

It is not my intention to trace at this time the development of the peneplains that mark the levels toward which the land was reduced, though such processes emphasize the great lapse of time required. The development of peneplains is considered in all the geologic reports of counties along the eastern portion of the state. In the development of those landscapes one stream became a master stream flowing toward the Atlantic. That stream is the Potomac, whose peculiar course gives evidence of the difficulty that it had in cutting through obstructions that were encountered. Toward the west the drainage centered in two lines, one along what is now the Kanawha, the other along the Monongahela. The waters of the Kanawha and its tributaries flowed far to the northwest across what is now Ohio. The waters of the Monongahela and its tributaries flowed north across what is now Pennsylvania. The valleys of old drainage lines in those directions are now found beneath heavy deposits of drift.

Many events occurred in those long intervals of time that followed the folding of the Appalachian region, for in West Virginia erosion was in progress, and the beds formed temporarily along the rivers were soon removed. The events are grouped into three Eras. The first included the closing episodes of the Permian, during which a mantle of ice left evidence of its presence even as far south as eighteen degrees north of the equator in India. Following this is the record of the entire Mesozoic Era, during a portion of which time an inland sea stretched from Mexico across what are now the western plains of the United States and across Canada to the Arctic ocean. This Era includes a time of folding that gave birth to the Sierra Mountains, and closed with a time of folding that gave birth to the Rocky Mountains.

After the events of the Mesozoic Era came the events of the Cenozoic Era, when the extensive plains that had formed along the Rocky Mountains became the abode of horses, camels, rhinoceroses, four-tusked mastodons, oreodonts, and other strange animals. Then came another great ice age, in which five great sheets of ice, one after another, occupied the northern part of the United States and Canada,

the most extensive glaciation reaching as far south as Cincinnati and St. Louis. Along the ice sheets lived the woolly mammoth and the musk ox. Farther south were other species of elephants, a mastodon, and several species of horses. Farther south still the region was invaded by strange southern forms, the giant sloth and the glyptodon. One of the sheets, presumably the Kansan (possibly the Nebraskan) clogged the drainage lines to the north and caused rivers flowing from the ice sheet to unite and form what is now the Ohio. It was during the flooding of these valleys that the Carmichaels clay was left along the river, and farther east and south striated pebbles that give evidence of vigorous ice action along the streams. On melting of the ice and on uplift terraces were left, some of which are very conspicuous in all parts of the state.

It is in the trend of geologic thought to work out the history of events in these long-continued intervals of time in which these various beds were laid down and later brought to light, and to learn what is possible of the changing conditions and of forms of life, both plant and animal, that thrived in those varied times.

There is no definite record of man in beds older than those which immediately precede the last, or Pleistocene, glaciation. Somewhat concerning early man is learned from the contents of mounds. The white man found the Indian using the state as a hunting preserve. The white man made his home along the river valleys, cut the timber, and sought the wealth hidden in the rocks. It is in the trend of geologic thought to determine the location of raw material in limestone, shale and sandstone. It is in the province of allied sciences to take out these resources economically, use them without waste, and turn over to the next generation, not bare rocks, with forests and soil gone from the mountains, and only fragments of beds of coal damaged through removal of underlying seams of coal, but to leave a well-timbered upland yielding a regular crop of timber, pasture lands where graze the finest of stock, quarries well managed, mines conserved, oil and gas more carefully utilized, manufactories developing innumerable products from these great resources, and a people awake to the beauty of their surroundings, appreciating the wealth of their hills, and happy under the just administration of wise laws.

It is the trend of geologic thought to develop not only a knowledge of the resources of our state, but also to develop an appreciation of that long past in which these various beds were laid down one after another, and develop an appreciation of the changes that have occurred leading to the mountains and the valleys as we now see them, and leading to a recognition of the central thought in geologic events—time; time not easily measured in years or centuries, but time measured by events, time reaching back through events well recorded in the strata, to time stretching back toward the dim unknown, but through it all law

and order of the Master Mind. Time reaching forward through the problems of the present to a distant future whose prosperity depends on the moral status of our people, and on the wise utilization of the wealth of Mother Earth in West Virginia.

## OUT OF DOORS WHERE I LIVE

## THE PRIZE ESSAY

By MISS DOROTHY GWINN,  
Elkins High School.

Across the street from where I live is a plot of ground that delights the heart of all nature lovers. Here one can observe the natural habits and tendencies of plant life, bird life and insect life; also man's part in caring for and directing or controlling their habits to suit his wish or needs. One part is a plebeian vegetable garden, the center of the plot is a hayfield, while all along the fence which surrounds the garden are flowers blooming continually from early spring till the frost kills them. Some flowers hiding modestly, others proudly erect as though conscious of their gorgeous hues, others like cheerful, busy, little people who are contentedly doing their share of work.

It is spring; a soft wind brings the smell of fresh, clean earth full of growing things across the street. I can see the little green shoots of early spring flowers peeping out of the soft, black earth.

Day by day the little green shoots become larger until one morning when I awake I see a yellow blossom looking at me as if to say, "Well, I'm here, don't you know Spring has come?" What a difference the first daffodil can make in a garden!

By and by there are many yellow heads in the garden and also some pink, white, and lavender bonnets. Hyacinths, to be sure, and their sweet odor permeates the soft, balmy air. The tulips nod their heads in the sunlight. They have a company all of their own. There are double tulips, fringed tulips, single tulips in a glorious array of colors. Spring is indeed in all her coming out colors. One particularly beautiful, tall, graceful tulip that wears a red bonnet seems to be peeping shyly at a nice, fat, sleek robin sitting on the branch of one of the trees near by. Mr. Robin's feathers are shining, and he has taken care that he is perfectly groomed for whom does he spy, but little Miss Tulip. He cocks his head to one side and winks one weather eye at her, then he expands his chest and begins singing his loveliest melody.

Now the gardener is out planting vegetable seeds in the other end of the garden. He prepares the soil carefully. It must be worked until smooth and fine for he knows the tiny seeds respond to careful planting, and the tender roots have a better chance to grow than if the soil were rough and full of clods.

Time passes and the little plants start to peep out of the earth and try their best to hurry, for their flower friends are ahead of them, and they too wish to share in the attention of passers by.

I watch them continue to grow and grow, and finally there is lettuce to eat, nice tender lettuce, and crisp radishes. The peas are putting

on their frilly white bonnets, giving the garden a "dressed up" look. All the while flowers are continuing to grow and blossom. I see new plants coming up and these prove to be nasturtiums. They grow rapidly and one can detect their spicy, pungent odor, and they are soon full of brilliant hued blossoms so attractive that each person, who sees them, wishes for a few to brighten up a dark corner of the home.

All of these flowers however have enemies—little insects begin to come and nibble the leaves, weeds begin to grow. A gardener finally comes and sprays the vegetables and plants with a solution that will prove disastrous to the insects and helpful to the plants. The gardener pulls the weeds that have sprung up and loosens the soil around the plants, so that they will have more room to grow.

The center of the plot of ground seems to be covered with a light green carpet, giving it such a restful look. It makes a picturesque background for all the garden activities and in the late summer it will be cut for hay, bringing a bit of rural life to the city streets.

The buds are appearing on the rambler rosebushes that climb the fence. The holly-hocks are raising their stately forms into the air. The bachelor buttons are spreading out looking like ragged, unkept vagabonds.

Now the rosebushes are in full bloom. They are in regal array along the fence, and they form a beautiful border for the rest of the flowers. One can fully appreciate the poet who said, "What is so rare as a day in June?" when one sees the profusion of red, pink, and white blooms so fresh and sparkling with dew, as the early morning sun first gleams upon them.

The hollyhocks are showing their blossoms, and the patch of bachelor buttons is of a brilliant blue and purple hue.

The bees are busily swarming around the blossoms gathering pollen which they store on their thighs, thus carrying the pollen to other flowers to fertilize them. Their drowsy humming fills the air and they are quite much at home for they have a special work around the flowers and are Nature's most energetic helpers.

And while the flowers are blooming all around the fence the grass and vegetables are growing. The vegetables are being used for the home and the hay will soon be ready for harvest.

In the evenings now, as the gardener waters the flowers with the hose, the sweet odor of the honeysuckle vine over in one corner of the plot fills the air.

The zinnias, marigolds, and goldenglow blend colorfully with the hay that is being cut. The clatter of the mower awakes the heavy midsummer air and the breezes carry the scent of new mown hay to all who are fortunate enough to live near this garden. The hay is stacked in piles and when thoroughly dried out it is put on a wagon

and hauled away. Now part of the ground is bare and empty, while the tomato vines on the other side bear ripe, juicy tomatoes.

We forget about the empty space as we gaze at the lovely array of asters and other late summer flowers. The dahlias make the most magnificent showing of all. Their various hues are due mainly to the fine climate that they have in which to grow. This part of the country is especially suited and noted for the beautiful dahlias—a plain flower yet having in its simplicity an attractiveness of coloring which no other flower possesses. Its leaves are plain, but with a fernlike foliage or possibly a plant called baby's breath the dahlias make very attractive and lovely bouquets for the home. Since the colorings are so numerous they make up for all the pale colors of the garden. The dahlias vary in size too. The large deep red dahlias seems to portray a deep secret in its golden heart. The large salmon dahlia might portray a rather flip-pant type and the pale pink one portrays a bashful and demure type.

However, these are only a few of the colors and no one can begin to write enough to describe them. The dahlias seem, in their magnificence, to be the most royal of the flowers, and all who come here marvel at their beauty.

Autumn is approaching and the leaves are taking on a faint tinge of yellow and red. The walnut trees along one side of the plot are laden with green balls that when ripe will be nuts to store away.

A bunch of tall, yellow flowers called goldenglow seem to be infested by armies of harmful bugs which need to be destroyed. Again the gardener sprays the plants and kills the insects at least for the time being.

The nights and days are growing colder and now the trees are robed in garments of most gorgeous colors. The whole earth seems to be dressed in her most majestic colors. The plot of ground is also a patch of brilliant hues.

The trees near the plot cannot keep their garments long for the leaves are beginning to fall. Some of them fall when they have their loveliest hues, others turn brown and fall to the earth. The wind blows through the trees and rustle, rustle, the leaves fall.

We hear a faint thud, thud on the ground. It is the walnuts falling from the trees, as the wind shakes the branches.

Most of the trees are bare now—only the graceful cosmos bedeck the barren plot of ground. A few dried-up bean plants stand in a row.

The leaves that have been discarded from the trees are being raked into large piles. The smell of the burning leaves fills the air which adds to the Autumn spirit. The ashes that are left leave a form of carbon that makes the ground richer and more fertile.

The leaves that have been missed by the rake remain on the ground to serve as a sort of covering for the grass when the frost comes.

We have noticed all through the different processes of the seasons

how the little plants each have some part in making the soil more fertile for crops and each plant has its special way of functioning and working.

A frost comes one night, and we think everything will be killed, but in the morning the patch of cosmos still remain alive, their delicate tints a striking contrast to the drabness of the rest of the garden. And when the very heavy frost comes we are sorry to see the last touch of beauty taken away but we know it must be.

There is always something to appreciate even if everything is bare and that is the beautiful sunset. The limbs of the trees now void of their leaves, enable us more easily to perceive the western sky in all its rosy light. The sky seems to be set afire and off in the distance the purple hills blend gorgeously with the whole setting. The branches of the trees appear fantastic and grotesque against the sky-line. One can imagine such wierd and fascinating stories about the figures on the horizon. Gradually the rosy light fades away and darkness descends. The wind rustles the branches of the trees, as though the earth is settling herself for the night.

The weather is getting cold and the bulbs are being tucked away in the earth for the long rest that gives them the strength and vitality to bloom for us again.

And when the winter snow covers the garden like a soft wool blanket in its white untrampled space we know that Nature is protecting the bulbs and roots and seeds waiting in the earth till the Spring. The snowbirds hopping around leaving little tracks in the snow seem to act as sentinels for all Nature's family under the fleecy, white blanket.

## SOME PROBLEMS OF NATURAL AND ARTIFICIAL REFORESTATION ARISING FROM WEST VIR- GINIA'S CUT-OVER TIMBER LAND

By THOMAS W. SKUCE,  
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### Land Utilization and Forestry in West Virginia

Few West Virginians appreciate the economic importance of the forest resources of the state. Sixty-three percent of the acreage of the state is forest land and the best crop to grow on it is timber. The skillful use and renewal of the timber crop on this land has been and will continue to be a contributing factor to the prosperity of the state, corporation, and individual. There are few activities in which the use of wood does not play an important part.

If West Virginia is to do more than play at true conservation she must substitute intelligent forestry for the careless and indifferent removal of her forests. Conservation in West Virginia resolves itself into a huge land problem. It is complex as is every other public problem. No cure-all can be found.

It will require the careful study and the concentrated action of all individuals, corporations, and public agencies of the state working together. This means the support of a public acquainted with the problem that is "conservation-conscious" and "Forest-minded." With such a unification of effort the natural resources with which West Virginia is so richly endowed can be built into a perpetual business for the state for all time.

Few people have grasped the interdependence of West Virginia's agricultural, commercial, industrial, and recreational interests. There are few who doubt the wisdom of expending millions for road development. Many thousands are spent on protection and propagation of game, truly a creditable undertaking, yet when it comes to financing the reforestation of her nine million acres of cut-over land, a few thousand dollars are doled out. This does not protect 60% of the forested area from fire. The remainder goes up in smoke both spring and fall.

We must have timber for use in continued coal removal and a stabilization of migratory forest industries to save the operator from scrapping his mill when present supplies become exhausted and the consequent abandonment of towns and breaking up of communities and homes of its workers to say nothing of the loss of revenue to the state.

So long as conservation or more properly speaking, the regeneration of the forests is predicated on any issue other than the basic one of intelligent land use, the problem is not being squarely faced and the solution merely postponed.

### Early Forest Land Management

As the first settlers pushed westward into Westphalia as that part of Virginia was then called, they found the area which was later destined to become West Virginia a veritable wilderness with its hills and valleys clad with a dense forest cover. This was a situation no different than had confronted the first settlers on American shores, so like their fathers these early pioneers had to cut, hew, and burn sufficient acreage to assure themselves a means of livelihood. As the fertility of the cleared hillsides became exhausted the process had to be repeated. Such a practice soon brought about through these circumstances a general hatred for the woods. This attitude was handed down through the years.

After having an area cleared, annual burnings were resorted to in an attempt to insure pasturage acreage. As a result it has become an accepted legitimate practice to the farmer in the hills for means of an imaginative improvement of his fields. In reality it is exceedingly detrimental to them in the end, even though there is a slight improvement in the immediate condition of the forage. Repeated burnings soon remove all vegetation and expose the mineral soil. This causes waste land, loss of revenue, land erosion and the encumbrance that idle land entails. Idle land is worse than no land at all since in the latter case no taxes have to be paid.

This condition has been disappearing down through the years as folks met the market demand for hardwood timber. The men engaged in this work were large business men aiding in the development of our state. Thirty to forty years ago intelligent men were wont to speak of the state's forest resources as inexhaustible. It was not realized that trees are a crop varying only from ordinary field crops in the matter of the length of time for maturing. These men were trying to handle their property in the most enlightened way so cannot be criticised too severely for a matter which was not known any more about than our forests were at the time.

Today West Virginia is dotted with thousands of barren acres and hundreds of deserted lumber camps. In a state having a 15,360,000-acre forest cover representing 99% of her total area there are 4,634,000 idle and cut-over acres and some 4,800 idle camp sites all due to the early failure to realize that trees were a crop and must be handled as such if lumbering is to become a stabilized industry in West Virginia. Restoration of this acreage to its original production of timber and the wise administration of the 9,000,000 acres remaining form the basis of the problem in West Virginia today.

In an effort to solve these problems several companies within the state have in their employ foresters who are busily engaged in trying to work out a feasible forest working plan. Hence it is the private owner

who has developed the real practice of forestry so far as it has gone in West Virginia. These same organizations have been handicapped in adopting anything more than a modified form of forestry practices due to land values, rates of taxation, land ownership, cost of protection to say nothing of the insidious workings of compound interest which serves as breakers upon which their efforts so far have stuck. Here is where the forest land owner needs state and public assistance.

To find the solution for these problems now has become a matter of public concern since we of the state must have timber. Surplus timber in other regions is fast becoming depleted and again such a large part of the West Virginia hills is fit for only timber production that if all land is to be kept producing its full share of revenue it is time that the public which forms the state of West Virginia take stock and give the situation serious consideration. These same problems confront the small land owners as well as the commercial operator.

Private effort cannot forever carry the entire load. To solve these problems it will take time and money which can well be handled by the state through a system of state forests such as exists in our neighboring states and others throughout the nation. Problems exist in West Virginia forests that cannot be solved by any blanket formula. They must be solved within the woods themselves. Forestry practices in France and Germany have been developed through such a system because the state backed by the public have been able to show the private owner practices that are both safe and economic. In so doing they have been able to bring about a perpetuation of forest crops.

Not only would such a program furnish a stabilization of industry but would also furnish a recreational policy that has its very backing in the woods themselves making for retreats dear to the hearts of campers, tourists, hunters, and fishermen alike.

#### **Present Forest Capital for Future Perpetuation**

Upwards of 125 species of native trees have been found in West Virginia but some of them are of little or no commercial importance. Of the timber in the original hardwood forests, approximately 30 percent was white oak, 15 percent other oaks, 18 percent yellow poplar, 12 percent chestnut, 5 percent maple, 5 percent beech, 5 percent basswood, with birch, hickory, ash, cherry, locust, walnut, cucumber, buckeye, sycamore and white elm as major species in the remaining 10 percent. Hemlock, spruce, white pine, cedar, and yellow pine were the leading softwoods.

West Virginia holds high rank in the production of many important lumber varieties. Until a few years ago, the state led the entire country in oak production and is still an important producer of oak lumber. West Virginia has led in the production of chestnut every year

but one since 1909, and is producing about a third of all the chestnut cut in the United States.

In 1925, West Virginia took second place in the production of yellow poplar, second in cherry, second in butternut, third in buckeye, third in basswood, fourth in maple, fourth in hickory, and fourth in oak. West Virginia was the only state to report a cut of cucumber magnolia.

For 1925, West Virginia produced the following percentages of important lumber varieties for the entire country:

Ash .....	2.3 percent	Hickory .....	8.7 percent
Basswood .....	11.4 percent	Maple .....	5.2 percent
Beech .....	6.5 percent	Oak .....	9.6 percent
Chestnut .....	33.9 percent	Spruce .....	4.5 percent
Hemlock .....	3.0 percent	Yellow Poplar ..	18.0 percent

For a number of years, West Virginia led all the states in the production of hardwood. Her greatest cut of hardwood in any one year was 907,547,000 board feet in 1909. This was also her greatest year for combined cut of hardwoods and softwoods, the total running to a billion and a half board feet. In production of hardwoods and softwoods combined, her best national standing was made in 1911 and 1913, ranking eleventh.

A comparison of exports and imports of lumber of both hardwoods and softwoods shows a big balance in favor of West Virginia over practically all states, except those who supply her with some pine. In other words, WEST VIRGINIA FURNISHES MORE LUMBER FOR THE USE OF OTHER STATES THAN SHE CONVERTS INTO THE FINISHED PRODUCT WITHIN HER BORDERS.

In 1924, West Virginia cut 614,289,000 board feet, of which 428,027,000 board feet went to other states, 61,198,000 board feet went overseas and 125,064,000 board feet was consumed in West Virginia. During the same period, West Virginia imported 227,616,000 board feet from her sister states.

Of the lumber shipped out of the state into other states and exported, 86,097,000 board feet was softwood and 403,128,000 board feet was hardwood. Of the imported lumber, 166,456,000 board feet was softwood and 61,160,000 board feet was hardwood. Of the West Virginia-produced lumber used at home, 23,214,000 board feet was softwood and 101,850,000 board feet was hardwood.

This furnished West Virginia a total of 189,670,000 board feet of softwood and 163,010,000 board feet of hardwood for local consumption.

But it should be remembered that the estimates of lumber production and consumption do not take into consideration heavy demands on timber resources for fuel, poles, posts, fence rails, cross ties, staves,

tan bark, mine timber or pulp wood, or the waste from lumber operations and the losses from forest fires.

#### Present Forest Land Status

While much of the original growth timber has been cut over there remains approximately 600,000 acres. In addition to this acreage there is a vast area of merchantable second growth available for operation.

Today 750 individuals and corporations own some 6,200,000 acres of potential timber land. The other 3,000,000 acres are in the form of farm woods distributed among 90,000 farmers.

In the seven counties east of the mountains 57% of the region or 1,265,890 acres fall in the category of forest land while in the fifteen counties south of the Great Kanawha River 80% of the area or 3,793,070 acres classify in like manner. For the remaining counties in the northern and central parts of the state 50% of the land surface is potential forest land with an acreage of 4,461,682 acres. The distribution shows 62.3% of the state best fitted for timber crop production or a good sized farm of 9,520,642 acres.

Realizing that timber is not an inexhaustible crop as was once supposed many owners who by force of circumstances are both coal operators and timber owners are beginning to look about for ways and means for full development of their properties upon a substantial basis. In forestry this ideal of a sustained yield toward which goal, efforts are directed presents a method of procedure that will bring about for the owners a permanent operation so far as timber land holdings are concerned.

The attainment of this ideal involves ownership of sufficient boundaries of land to insure compartments for progressive cutting so that at the end of a given cycle the process may be repeated. Nowhere in the eastern United States is there a better opportunity for such a practice than here in West Virginia where acreages of sufficient size are in private ownership in an operating way. This involves additional problems of land management but goes a long way in giving this state the lead over her eastern neighbors who are cut out and whose remaining operating areas are broken up into small units.

As has been previously pointed out this state is producing more timber for final manufacture in other states than at home, yet there are a large number of operating concerns dependent upon the product of the log for their existence. The list below gives some idea of the diverse uses into which wood enters as well as a realization that in the communities where many of these plants are located they supply a goodly share of the employment available.

## West Virginia Users of Wood

User	No. of Concerns
Aeroplanes .....	2
Baskets and Fruit Packages .....	6
Barrels and Kegs .....	5
Boat and Ship Building .....	5
Boxes and Crates .....	44
Brushes and Brooms .....	3
Car Construction .....	20
Caskets and Coffins .....	4
Chairs and Chair Stock .....	7
Fixtures .....	7
Cross Arms Insulator Pins .....	10
Dairymen and Poulterers' Supplies .....	4
Excelsior .....	3
Furniture .....	25
Gates and Fencing .....	5
Handles .....	24
Laundry Appliances .....	3
Machine Construction .....	15
Matches .....	2
Musical Instruments .....	1
Patterns and Flasks .....	26
Pencils .....	1
Picture Frames and Molding .....	9
Planing Mill Products .....	167
Playground Equipment .....	5
Plumbers Woodwork .....	2
Pulp and Paper .....	15
Pulleys and Conveyors .....	3
Ready-cut Houses .....	2
Refrigerators and Kitchen Cabinets .....	6
Sash, Doors and Blinds .....	53
Sporting Goods .....	2
Vehicles and Vehicle Parts .....	5
Veneer .....	6
Woodenware and Novelties .....	5
Wood Pipe, Tanks, Silos and Vats .....	4
Wood Preserving .....	2
Total—37—.....	498

One hundred and ten major sawmills cut 90% of the annual production. These mills are of the permanent class while approximately

920 portable sawmills move from place to place cutting small boundaries representing 10% of the annual output.

In addition to these concerns engaged in the field of wood production, manufacture and utilization are the railroads, with a huge annual cross tie replacement item each year; public utility companies, one of these operating in the Morgantown area has an annual replacement of 600-750 poles. Telephone companies need a large number of poles each year. Additional timber goes into mine timbers, posts, pulp wood, etc.

Suffice it to say that a glance at the given table shows that the number of employees and value of the products turned out returns a handsome revenue to the state:

Articles Manufactured	Number of Employees	Value of Produce
Boxes .....	157	\$ 1,168,000
Railway and street car construction and repair .....	12,111	33,842,000
Cooperage .....	96	635,770
Furniture .....	811	4,177,000
Leather .....	1,203	13,348,000
Lumber .....	9,979	35,035,000
Paper and pulp .....	916	6,707,000
Ship and boat building .....	178	918,858
Total .....	25,451	\$95,831,628

A realization of what this industry means has led owners and operators to ask some perfectly legitimate questions which involve information which is not now available in this state.

The mine owner wants to know where he can secure suitable material at reasonable cost; the timber land owner asks how much timber he must have per acre to warrant building a mile of railroad to get it; the pulp and paper industry wonder what is a reasonable period of expectancy for different species to mature for pulpwood. These questions and many others such as carrying charges and insurance rates for fire protection, etc., arise every day. The farm woodland owner asks what methods are best to dispose of his material to insure a thrifty future growth as well as the best method to insure future regeneration. These and many others are fair questions that can be answered only through research and experience in the woods.

#### Mine Timber Situation

In 1923 there were 1286 bituminous coal mines operating in West Virginia. Nine hundred and sixty-four or 75% of this number reported having used 17,429,909 cubic feet of round timber or a total

for all mines of 21,787,384 cubic feet, at an average cost of 16 $\frac{2}{5}$  cents a cubic foot. The total cost for this material was \$3,583,130. In addition to this round material the same 1286 mines used 61,895,000 board feet of sawed timber at a cost of \$29.50 per thousand board feet, or a total investment of \$56,850, or in other words the timber bill for the 1923 output of 97,475,177 tons of coal required a timber bill of \$5,439,980.

In 1927 with only 1250 mines operating the year's output reached the highest on record for West Virginia of 146,088,121 tons. This makes our timber bill almost double due to higher timber prices, and the need for more timbering in some mines over others. The timber bill for the year 1927 was approximately \$9,875,000 shown by the figures from last year's U. S. Department of Commerce figures.

All species of timber are used except pine and poplar which are not long lasting enough under ground. The miners prefer long-grained timber such as chestnut, oak, maple, ash and the like since these timbers crack and split long before they break and thus gives the miners a warning when a settling of the earth structure overhead occurs. Short grained woods are not desirable as they break without warning.

However, other species are used such as beech, hemlock, and poplar even though not always desirable.

Where does West Virginia mine timber come from? In the southern part of the state a greater part of the material is shipped in from south-western Virginia and other states. However, with pulp mills moving into that section of Virginia the mine timber that heretofore has been coming to West Virginia will remain within that state, due to the new rod mill process for paper making. Props and mine timber cut locally has been taken up to 12 inches with nothing allowed to become any larger.

In the northern part of the state all material has to be shipped in because the local timber supply is less than elsewhere in the state. Pennsylvania, Maryland, and Eastern Panhandle counties of this state all contribute.

How long can this be kept up and what is to become of the timber producing surface? With nine million acres available for this purpose and an ever increasing necessity of cutting production costs to meet competition it would seem a wise move to begin thinking of having a home mine timber supply to meet the demands.

The situation was well stated by one purchasing agent recently with the remark that "Today our problem is not so much a question of price but where can we secure the kind and amount of suitable material?" Why not all join forces and insist on having it raised at home?

#### Farm Woodland Needs

In spite of the fact that many West Virginia farms are in small

units of from 50 to 100 acres, the aggregate amount of farm timber in the state is approximately three million two hundred and fifty thousand acres, or more than a third of the total wooded area of the state. The annual expenditures on West Virginia farms for forest products, such as lumber, posts and firewood, averages \$113. per farm, according to the U. S. Census, and represents a total outlay for the farmers of the state of more than ten million dollars per year. In some sections of West Virginia, the income from the woodlot is from 20 to 30 percent of the entire return from the farm.

There is need by the farmer knowledge of thinning, through the right kind of cutting; protection of the woods from fire and other injuries; estimates of the board content of standing timber; a knowledge of the market demands for sizes and kinds of trees; reclamation of gullies, rocky, steep, burned and eroded areas through planting of proper tree species; and better utilization of the farm timber already available in order to keep the woodlands growing at their maximum rate of production.

Most farmers know how many bushels of corn they have in the crib and the number of barrels of apples their orchard will produce, but few of them know the log content of the trees in the woodlot.

This inability cost one farmer in Mineral County \$498. He sold his timber at \$6. per thousand on the stump, based on a haphazard local "cruise" of 50,000 board feet. When the material was measured up after it had been through the mill, there was a total of 133,000 board feet of lumber.

In Randolph County, a farmer sold good black walnut logs for \$50. a thousand along the state road while his neighbor, ten miles back, held on to his walnut and received \$90. because he had secured information on the black walnut market.

Much material goes for ties and props which should be left a few years or which would command a higher price if marketed in some other form, such as veneer, furniture stock or lumber.

The experiences of woodlot owners in Nicholas and Webster counties point out very clearly that the burning of logging slash, even when carefully controlled, causes marked decrease in the growth and health of the timber.

One woodlot of 30 acres has been burned over twice. The large, select yellow poplar was cut on this tract 30 years ago, a second cutting was made 11 years ago and a third three years ago for lumber, ties, posts and mine props.

The second woodlot, a tract of 50 acres, has had no fires of any kind in the past 25 years. It was first cut over for poplar, a second cut was made 17 years ago for lumber and ties, taking trees down to 14 inches on the stump, and the slash was left on the ground to rot.

The better condition of the unburned woodlot is so marked that

any farmer can see it. To remove fire hazard, woodlot owners are urged to dispose of "slash" by lopping and scattering the tops and branches instead of burning them.

With study, the farmer can learn to handle his woodlot just as he does any other crop, and in this way he will make it pay its biggest dividends. The farm program must be enlarged to include the woodlot's proper management. All the land on the farm should bear its part of the burden by yielding an income, and the woodlot can be made to occupy a very important place in a progressive program of land utilization.

Since West Virginia as a state must depend very largely for its economic development upon the wise use and manipulation of her natural resources, it would seem that considerable thought and effort should be given toward the full use and care of the same. True conservation is a progressive development through wise use. Similarly forestry is the efficient cultivation and management of woodlands in a scientific manner for profit.

Timber growing is no longer regarded as something outside the range of business consideration, although private forest management cannot at best extend either fast enough or far enough to afford by itself a solution of the forest problem it must be encouraged by public effort. Conditions must be made more favorable for its extension, for what is at stake is the efficient economic use and continuous productiveness of 9,000,000 acres of privately owned forest land in this state.

The most practical means of encouraging this is through practical demonstrations. Dr. Knapp in beginning his unique system of adult agricultural education through field demonstrations in 1903 little realized how far reaching it was to become, but it is the most effective means of getting across the best woods practices as well as agricultural procedure. Forest land owners will do some work on their properties but want to know how and what is the best methods of procedure. They want to see forestry in a practical way.

The last legislature took cognizance of the forest land situation in this state when it enacted a measure expanding the Game and Fish Commission to include two major divisions, namely, game and fish and forestry, the work of game protection remaining as it has in the past under a chief game protector, while forest activities will be in charge of a state forester or chief forester as the law designates the title of this office. Under the new Game, Fish and Forestry Commission then it is to be expected that a great many of the problems now facing us will be worked out in a program that can progressively be developed to meet the needs as they exist in West Virginia.

To handle these forest problems of West Virginia properly will require continuous study. Definite information must be available concerning stable practices before any changes from present procedure

can be effected. Nothing can be extended without something to extend.

Any program adopted on the part of the state no doubt would include in its makeup cooperation with the research agencies within the state in developing this part of the work. This is as it should be because as a land problem the question allies itself closely with the agricultural problem.

The several lines of forest research or projects needing consideration can best be listed in the following manner:

#### 1.—FORESTATION.

(a) **Nursery Practice.** To determine the best methods of nursery practice and their results, covering all stages from seed collection and storage, to the seedling or transplant ready for planting out.

(b) **Species for Forest Planting.** To determine the best species for forest planting on various sites and for various products or purposes, also to observe and record results in growth, yield, etc.

(c) **Forest Planting Sites and Planting Methods.** To determine the best method of forest planting using various species and sizes of stock on various sites and under various conditions of cover, etc., and the cost of each.

(d) **Forest Planting in Mixture.** To determine the practicability of planting various species in mixture.

(e) **Converting Hardwood Stands to Conifers by Planting and Natural Seeding of Mixed Stands.** To determine methods of planting and converting poor stands of hardwoods to coniferous stands and bringing back conifers in mixed stands.

(f) **Growing Christmas Trees.** To determine the best methods for growing trees for Christmas use.

(g) **Strip Mine Planting.** Determination of suitability of certain hard pines to cover spoil banks around mine operations that have been abandoned, namely, in the case of the condition existing at Meadowbrook in Harrison County.

(h) **Direct Seeding.** To determine the possibilities of direct seeding of incompletely stocked forest areas.

(i) **Forest Conversion Studies.** To make a study of the different methods of converting inferior hardwoods to stands of valuable forest trees. These studies aim to find methods that are silviculturally feasible and economically recommendable.

#### 2.—PROTECTION.

(a) **Study of Fire Prevention.** To determine from records the best methods of fire prevention and suppression covering all phases of organization, etc.

(b) **Fire Lines.** To determine what constitutes the best fire line under different conditions.

(c) **Fire Damage to Timber and Tree Growth.** To determine injury

and damage done to trees and stands of various species, ages, sizes and conditions on various sites by fires of various degrees of severity burning at various seasons.

(d) **Cost of Fire Protection.** To determine by past and present records the relationship between cost of protection organization and damage by fire, to forest values, in order to determine the proper amount of expenditures for protective work.

(e) **Forest Fire Hazard.** To determine how forest fire hazard is affected by weather, types of growth, topography and human agencies.

(f) **Protective Organization and Forest Fire Tactics.** The comparative results produced by different kinds and types of organization, division of territory, use of apparatus, lines of communication, lookout system, methods of extinction, etc.

(g) **Public Relationship.** To determine the most effective agencies for obtaining public cooperation for fire prevention by keeping records of the effect of press articles, posters, talks, etc., on the number of fires.

(h) **Railroad Fires.** To determine the best way to suppress railroad fires from the study of fire lines, mechanical devices for engines, patrols, laws and regulations.

(i) **Prevention of Fires from Brush Burning and Campfires.** To determine the best way of preventing fires due to those causes, by the study of the effect of laws, regulations and publicity effecting them.

(j) **Effect of Grazing in Woodland.** To determine the effect of grazing of various animals in plantations, the damage done to various species and to trees of various sizes by eating or trampling; also the effect on reproduction of various species in woodlands. Also to determine what beneficial results, if any, may result from grazing plantations established among hardwoods sprouts.

### 3.—MANAGEMENT.

(a) **Demonstration Forests.** The establishment and development of Demonstration Forests in all parts of the state, covering all kinds of forest operations, including planting, thinning, pruning, fire protection, utilization, etc. Accurate growth and cost records to be kept of all operations in each project.

(b) **Forest Types of West Virginia.** Special study of all forest types of West Virginia, giving their composition, principal indicator species, distribution, and major sylvical peculiarities.

(c) **The Slash Disposal Problem.** A study to secure fuller and better information on the proper disposal of slash following lumber operations.

(d) **Tulip Poplar in West Virginia.** A complete study of the characteristics, occurrence, behavior, growth and yield of Tulip Poplar in

plantations and natural stands. The results of this study will determine its use in West Virginia.

(e) **The Black Cherry in West Virginia.** A complete study of the history, characteristics, occurrence, behavior, growth, yield, and wood uses of this tree in West Virginia.

(f) **Black Walnut in West Virginia.** A complete tree study of Black Walnut in West Virginia. Special consideration should be given to its characteristics, local occurrence, local silvicultural peculiarities, growth, and yield.

(g) **The Results of Thinning and Improvement Cuttings.** To determine the yield of products and cost of thinnings and improvement cuttings, the resultant growth and yield products.

(h) **Practice of Forestry by Private Owners.** To determine the extent to which forestry is being practiced by private owners, the character of the work done and the results secured.

(i) **Management of Hardwood Stands.** To determine best methods of thinning improvements; securing reproduction, and general management of hardwoods.

(j) **Management of Second Growth Hardwood Stands.** Determine the best method of thinning, improvement as to quality, quantity and species, and general management of second growth hardwood stands throughout West Virginia.

#### 4.—MENSURATION.

(a) **Volume Tables.** To construct accurate and usable volume tables of West Virginia timber species of economical importance not now available.

(b) **Growth and Yield Studies.** To determine growth and yield of various pure and mixed stands and types in various conditions, sites, and ages, in natural stands, plantations, and in stands improved or thinned.

(c) **Mill Scale Studies.** To compare actual mill cut of various species and products in mills of all degrees of efficiency, with volumes given by standard log rules and volume tables.

(d) **Growth Yield of Tulip Poplar.** To determine the yield in volume from forest stands in which this tree predominates and is favored, and to determine what degree of thinning is best.

(e) **Growth and Yield of Mixed Oaks.** By studies in permanent sample plots to determine growth rate by individual trees and in stands. By varying treatment determine kind of silvicultural management best adapted to them from standpoint of increment and reproduction.

#### 5.—ECONOMIC.

(a) **Land Utilization and Forest Survey of West Virginia.** To determine the amount, kinds and condition of present timber stands in

West Virginia, and also the classification of land from the standpoint of best utilization.

(b) **Forest Land Taxation.** To ascertain the best methods of assuring forest land its maximum opportunity to produce a full crop at a rate that warrants the landowner holding his land, and yet producing the requisite revenue for the support of local government.

(c) **The Forest Situation in West Virginia.** A progressive study of the forest situation in West Virginia, collection of data on forest area, wood production, wood consumption, forest yield, etc.

(d) **The Forest and Water Supply.** A study of the water supply situation and its inter-relation with forest cover.

#### 6.—**ECOLOGY PROJECTS.**

(a) **Leaf and Litter Production of West Virginia Trees.** To determine by sample tree and plot counts how many leaves are borne per acre of forest by important forest trees and forest types on different site qualities; also to ascertain what is the total leaf surface exposed per acre and per tree of different species and diameter of classes. What is the dry weight and mineral ash content of the leaves, and what is the extent of variations from year to year, are two of the questions to be considered.

(b) **Transpiration and Evaporation.** To determine the relation between evaporation and transpiration in stands of various density, especially as a factor in conserving underground water on watersheds.

#### 7.—**UTILIZATION.**

(a) **Wood Using and Producing Industries in West Virginia and Vicinity.** To secure and keep up-to-date an accurate record of wood producers and wood users, and markets for timber and wood products.

(b) **Logging Methods and Costs.** To determine best methods and costs for logging various kinds of timber or products in different forest regions in West Virginia.

(c) **Timber Operations.** To keep a list of wood users and their needs.

(d) **Sugar Maple Industry.** Investigation of maple sugar industry with special reference to producing the product and marketing same.

(e) **Lumber Dry Kiln Efficiency.** To determine the efficiency of different kinds of dry kilns.

(f) **The Pulpwood Industry in West Virginia.** A survey of the pulp industry of West Virginia.

(g) **The Tanning Industry in West Virginia.** A complete survey of the tanning industry in the state.

(h) **The Mine Timber Supply.** A complete survey of uses and

purposes for which various species are used along with demands for underground timber.

(i) **Preservation of Mine Timber.** To lengthen life, reduce cost, and drain on available supplies.

#### 8.—DENDROLOGY.

(a) **Big and Historic Trees in West Virginia.** Collection of information about the big and historic trees of West Virginia.

(b) **Introduction of Exotic Trees.** To grow as arboretum specimens and under forest conditions a large number of exotic tree species of temperate climes.

(c) **Dendrology of Native Species and Exotic Species Used for Reforestation.** To determine the range, habits of growth and other characteristics of all native tree species and exotics used for planting.

As to the desirability of such a program of action as has just been outlined we have but to refer to the optimistic statement of Mr. John Raine summing up the lumber outlook for West Virginia for 1929. Mr. Raine is President of the West Virginia Lumbermen's Association, and also President and General Manager of the Meadow River Lumber Company located at Rainelle, Greenbrier County. This company operates the largest triple band hardwood mill in the world.

Mr. Raine says in part: "The lumber industry faces an era of progression if it survives. The present era of slaughter and waste must cease.

"An era of conservation on broad state lines; of full utilization of forest products and their conversion and fabrication in our own industrial plants, using West Virginia labor must ensue, if the state wishes to perpetuate the lumber industry. Now is the time to begin."

Through the initiation of such work in the attempt to find the answer to the knotty problems presented West Virginia agencies cooperating can render an effective service that should merit the whole hearted support of the commercial, public, industrial, and agricultural agencies of the state.

AN ECOLOGICAL STUDY OF THE ALLEGHENY  
CLIFF RAT

(Neotoma pennsylvanica Stone).

By C. L. NEWCOMBE,

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While traveling through the State of West Virginia during the summer of 1928 with the West Virginia University Biological Expedition, engaged in ecological study, the attention of the writer was attracted by a large accumulation of vegetable debris on a shelving ledge of rock. An examination of this rubbish heap and the adjacent rock revealed the fact that it was the home of the wood rat—*Neotoma pennsylvanica* Stone. This species is known by several common names of which "Allegheny Cliff Rat" is the most popular. It is our only native West Virginia rat and was first collected on December 2, 1892, by Witmer Stone ('93) at South Mountain, Pennsylvania.

The Allegheny Cliff Rat is a little larger than the common Norway Rat, gray in color on the dorsal side, with the underparts almost white. At first sight, one is immediately impressed by the long vibrissae (whiskers), conspicuous ears, and large bright eyes which tend to give an expression even more animated than that of the squirrels; and in agility and rapidity of movement, these rats are comparable to the frisky chipmunk of the forest. They are, in the main, nocturnal animals, very timid, and seem to possess an instinct for gathering unusual quantities of plant materials. They have a musky odor, but their flesh is white and delicate, and it is said to be more palatable than that of either squirrels or rabbits.

Although probably still abundant in many localities, *Neotoma pennsylvanica* is far less common now than it was in former years. Reports indicate that in the early days it frequently came into the houses of settlers and had the habit of carrying away dried fruits and almost any other small object within its grasp. However, little economic significance can be attached to this species of wood rat since, dwelling in the more remote parts of the mountains, they rarely cause any damage.

During the winter of 1909-10, wood rats were quite abundant at Franklin, West Virginia, where a large colony was living on a ledge of rock near the town. They have also been reported in considerable numbers from Circleville, Pendleton County, West Virginia. Goldman ('10) of the United States Biological Survey, lists eleven specimens from Franklin, one from Hillsboro, and twenty-one from White Sulphur Springs, Greenbrier County, West Virginia. Outside of West Virginia they have been collected at Woodville, Montano (near Huntsville), Tennessee; Gunter's Mountain (near Fort Deposit), Alabama; from the

northern shore of Muscle Shoals, Alabama; Mammoth Cave, Haversville, and Jackson, Kentucky; as far north as the Ohio River; also at Lost Creek, Breathitt County, Kentucky. Bailey ('96) in his "List of Mammals of the District of Columbia," states that wood rats of the species *Neotoma pennsylvanica* are common in cliffs, caves and rock slides along the west side of the Potomac River from Chain Bridge to Great Falls, but that no trace of them has been found on the east side of the river. In general, its range is the Appalachian Mountain system, from Hudson River, in southern New York State, to northern Alabama where its distribution is apparently limited by the Tennessee River.

Although the wood rat is generally found in relatively high elevations, an individual of this species was collected by Dr. A. J. Dadisman from Cornwall's cave situated about one hundred feet above Cheat River, six miles from Masontown, West Virginia. Rats were discovered here in 1916 by Dr. A. M. Reese and he also collected a nest built by these rats. In this same cave, during the fall of 1928, the writer observed one of the rats of this group approximately two hundred feet from the entrance, and the presence of a large amount of excrement would seem to indicate that this cave was a permanent residence of this species. Unlike its neighbor, the Florida wood rat (*Neotoma floridanus*), *Neotoma pennsylvanica* is never found in lowland swamps.

The first and perhaps the most interesting habitat, from the point of view of location and quantity of materials present, was found July 1, 1928. The nest proper was located on a high ledge of Price's Rock, a great mass of sandstone approximately fifty feet high, situated on a small mountain ridge about four miles from Madison, West Virginia. In front of the entrance leading to the nest, which was invisible from the outside, there was a pile of vegetable debris consisting of at least two bushels of sticks, leaves, nuts, shells and other rubbish. At another place on the other side of the rock there was a similar accumulation of materials.

For the want of a more satisfactory, specific term I have adopted the word "midden" to designate the heap of sticks, leaves, bark, shells of nuts, fungi, fragments of fruits, and other materials, invariably present in the immediate vicinity of the nest. In most cases the nests proper are found deep in crevices of the large rocks on top of mountain ridges in rather inaccessible places, and are in this way protected against their enemies.

The various nests found seem to be quit uniform in both size and composition. They have the general shape of a robin's nest with a diameter of about 250 mm. and a depth of 75 mm. They are composed of fine, soft, fibrous material, consisting mainly of the bast fibers of chestnut (*Castanea dentata*) and Basswood (*Tilia heterophylla*). Careful examination of the nest seemed to establish quite conclusively that rats of this generation had used the nest of their parents.

English ('23), in his work on the Dusky-footed Wood Rat (*Neotoma fuscipes*), says, "In making an extensive study of the nest-building habits of wood rats in this locality, my conclusion based on two years' work is that the rats of the succeeding generations use the nests of their parents, each year adding more material on to the old nest. For this reason we sometimes find very large nests in isolated places. However, if the colony increases rapidly, conditions will be too crowded for all to live in the same nest, hence we find newer, smaller nests under construction and the springing up of a large colony of nests in a given community." Usually the nest proper is reached by two or more entrances, thus facilitating easy escape of the rats when attacked by enemies.

The most conspicuous result of the work on rats is not the nest proper but the "midden." A great variety of plant material including acorns, chestnut burrs, chestnuts, leaves, stems and fungi, was found to constitute the bulk of the debris. In the "midden" on a ledge of Price's Rock were found sticks of various sizes, the largest being about 450 mm. in length and 37 mm. in diameter. Young twigs and leaves of the Juneberry (*Amelanchier canadensis*) were abundant and a moss (*Dicranum* sp.) was present in considerable quantities. The presence of numerous bits of paper, a piece of rubber from an automobile tire and two or three shotgun shells, which were much gnawed, were interesting items of the rat's collection. Since no paper or rubber was used in the construction of the nest proper, the question arises concerning the probable reason for the collection of such material. That certain animal organisms furnish a part of these collections was clearly indicated by the presence of shells of several common woodland snails and the empty shells of a few duck eggs. A careful examination of one of the rubbish heaps revealed the presence of the following materials:

Common Name	Scientific Name
Fern fronds . . . . .	<i>Polypodium vulgare</i>
Coral fungi . . . . .	<i>Clavaria</i> sp.
Toadstool . . . . .	<i>Agaric</i> sp.
Acorns and leaves of Red Oak . . . . .	<i>Quercus rubra</i>
Twigs and leaves of Juneberry . . . . .	<i>Amelanchier canadensis</i>
Leaves and fruits of Asters . . . . .	<i>Aster</i> sp.
Leaves, bark and blossoms of	
Chestnut Oak . . . . .	<i>Quercus prinus</i>
Moss . . . . .	<i>Dicranum</i> sp.
Twigs of Sweet Birch . . . . .	<i>Betula lenta</i>
Twigs of Scarlet Oak . . . . .	<i>Quercus coccinea</i>
Lichens . . . . .	<i>Parmelia</i> sp.
	<i>Umbilicaria pustulata</i>

Fragments of Goldenrod . . . . .	<i>Solidago caesia</i>
Nuts of Mocker Nut Hickory . . . . .	<i>Carya alba</i>
Chestnut Burrs . . . . .	<i>Castanea dentata</i>

During the fall of 1928 a nest was discovered at Mitchell's Knob situated on Chestnut Ridge, twelve miles from Morgantown, West Virginia, at an elevation of approximately 2,600 feet. Judging from the amount and condition of the material gathered and the excrement present, the nest had been occupied for a considerable period of time.

Observation of the materials of the "midden" revealed the fact that stems are cut obliquely on one side as distinguished from the circular manner in which beavers cut sticks, thus showing an element of consistency in the process. Leafy twigs of the wild black cherry (*Prunus serotina*) which were probably the most plentiful of any one type of vegetation present in the "midden," were invariably folded back once and often two or three times, forming sort of a compact mass of leaves and stems wadded together.

An attempt was made to determine in a general way the relative quantities of the various materials accumulated in the "middens" at Mitchell's Knob. The following list gives the result of this study\*.

#### Most Plentiful

Common name	Scientific name
Sweet Birch: twigs and old outer bark . . . . .	<i>Betula lenta</i>
Staghorn sumac . . . . .	<i>Rhus typhina</i>
Pin Cherry (Particularly leaves) . . . . .	<i>Prunus pennsylvanica</i>
Rhododendron: twigs . . . . .	<i>Rhododendron maximum</i>
Gill Fungus . . . . .	(?)
Chestnut (bast fibers) . . . . .	<i>Castanea dentata</i>
Wild Black Cherry . . . . .	<i>Prunus serotina</i>
Black Elder (young twigs with leaves attached) . . . . .	<i>Sambucus canadensis</i>
Fungus (puff ball) . . . . .	<i>Scleroderma vulgare</i>

#### Less Plentiful

Red Oak: leaves . . . . .	<i>Quercus rubra</i>
Oak twigs . . . . .	<i>Quercus sp.</i>

#### Materials Present in Smaller Amounts

Acorn fragments . . . . .	<i>Quercus sp.</i>
Fungi . . . . .	<i>Boletus sp.</i>
	<i>Russula sp.</i>
	<i>Inocybe sp.</i> (and several other genera of Agaraceae not identifiable).

(\*) For the identification of the fungi, I am indebted to Dr. W. A. Archer of the Plant Disease Survey, U. S. Dept. of Agriculture, Washington, D. C.

Chestnut shells . . . . .	Castanea dentata
Rhododendron leaves . . . . .	Rhododendron maximum
Sassafras leaves and twigs . . . . .	Sassafras variifolium
Sweet Birch leaves . . . . .	Betula lenta
White Snake Root . . . . .	Eupatorium urticaefolium
Wild Apple (mainly cores) . . . . .	Pyrus malus
1 crow feather	
1 turkey feather	
1 small rubber band	

It is interesting to note that in addition to the plant materials there were included here one crow feather, one turkey feather, and a small rubber band. Since rubber forms a part of the accumulations in both instances, one might possibly infer that the odor of this material is the characteristic that attracts the rat's fancy.

Quoting again from English ('23): "The wood rats are very particular about their food. For example, when you bring in a variety of fresh cuttings and offer one to a rat, if the food does not suit its fancy, it will not touch it. However, if one bites off a twig and starts eating, the others, on hearing one of their number eating, will promptly do likewise. At times they will cut off a twig and carry it to the nest, to eat it in seclusion, and then come back for more. Again they will remain near the supply and eat until they are satisfied, holding the material in their front feet and eating all they have cut off before attacking more, thus making little waste of green succulent material. It is impossible in fact to induce them to take more than they can hold in their front feet. Occasionally they fight over the food; such a brief disturbance may occur if one rat is eating and another rat steals his supply; a brief chase and a momentarily ruffled temper ensue." As far as the writer has been able to determine, similar reactions take place in the case of *Neotoma pennsylvanica*.

Examination of the "middens" of several habitats revealed the fact that fungi of different species form a regular constituent of the rat's collections and are usually present in numbers that are significant. Parks ('23) in his paper entitled "The Genus of *Neotoma* in Santa Cruz Mountains," tells of finding in the habitats of these rats seven species of a certain fungus, all aromatic, and says, "I assumed that these plants were desirable for food for the rats, and associated the many excavations which I had been finding, with the work of the Wood Rat. I also assumed that there must be some relationship between the location of the nests and the location of desirable fungi. The conclusion arrived at after considerable study was that where the wood rats were numerous, the Fungi must likewise be abundant." Careful inspection of the abundant and various fungi collected by *Neotoma pennsylvanica* did not reveal tooth marks or any conclusive evidence of their being collec-

ted for food. Specimens in captivity were given fungi, the outer surface of which, in every case, was nearly all consumed, a result which points quite conclusively to the fact that wood rats of the species *Neotoma pennsylvanica* collect and store fungi for winter consumption. Buller ('20) states that collective evidence would indicate that storing of fungi in the branches of trees in the autumn by the Red Squirrel is a well-developed instinct. Judging from the consistency, industry and care with which collections were made, one would be amply justified in accepting a similar explanation in the case of *Neotoma pennsylvanica*.

Climate is a very important factor in determining whether or not fungi are stored for food purposes by rodents such as squirrels, rabbits or wood rats. As far as we know, the English squirrel does not include fungi in its winter store of food, the reason being that the dampness and mildness of the English climate cause the fleshy fungi to rot rather quickly. In northern United States and southern Canada, however, the climate during the fall and winter season is cold with slight precipitation in the form of snow. Quoting again from Buller ('20): "Owing to the dryness and coldness of the climate, the fungi hung in the branches of trees by squirrels in late autumn, dry without rotting and remain good to eat until spring comes, while those deposited in bulk in holes, although moist when collected, become partially dried and, in this condition, preserved by the action of the frost. The fungi heaped together in holes, etc., are put by the weather into a state of cold storage resembling that in which mankind now preserves many of his food-stuffs, such as beef and mutton. The storage of fungi for the winter, by increasing and varying the supply of food, is undoubtedly beneficial to the Red Squirrel and is due to an instinct which appears to have been developed in response to severe winter conditions."

No studies were made on the food of this group under natural conditions. Natural environment is the only true basis for a study of this kind since to change the natural habitat of an animal results in a modification of its behavior—an adaptation to the new conditions by process of selection of those elements most nearly resembling the elements of the natural habitat. Obviously, then, too much emphasis must not be attributed to behavioristic tendencies manifested under artificial, environmental conditions unless a very long period of time has been allowed for adjustment to these unnatural conditions. With these facts in mind, the writer presents the following results of food experiments, by no means conclusive, which were carried on in duplicate in the laboratory.

The two rats were placed in different cages and fed the same kinds of food in equal amounts; with a view to determining food preferences of the species, three kinds of food were given them simultaneously, care being taken to include in each feeding one type that was evidently relished to avoid the possibility of starvation. However, in

each trial feeding, the food desired most by the rats was offered in small quantities, in order that they might be kept sufficiently hungry to justify the expectation that that would partake of other available food materials that were less desired. They were given the same food for periods of ninety-six hours, two feedings having been made during this time, each at five o'clock in the afternoon. The food materials which they ate are arranged in order of preference:

1. Nuts of various kinds.
2. Sweet potatoes, apples, grapes.
3. Carrots, cabbages, lettuce.
4. Spinach, cheese, tomatoes, radishes, oranges.
5. Celery and onions.

Of all the nuts, they like Chestnuts best; the next in order of preference being acorns, almonds, English walnuts, and Brazil nuts. They would not eat bacon, liver or Irish potatoes.

In addition to the foods discussed above, hens' eggs and lemons were placed in the cage. For a long time the eggs were not touched by either rat. Finally, however, after the shell had been broken, the egg in one cage was eaten. Of all the fruit used in the experiment, lemons were liked the least, being eaten only when the rats were very hungry. The average amount of water consumed every forty-eight hours during the experiment was about 100 cc. During several days, milk was substituted for water, and practically the same quantities were consumed.

Of the six specimens collected at Mitchell's Knob, one young and one old female were taken alive. Observations of these living specimens in captivity were made during a period of two months. No signs of unusual behavior were noticed, but as time went on the animals seemed to become resigned to their new environment. At first excelsior was placed in the cage, and immediately the rat proceeded to rearrange the woody threads in the construction of a nest, fashioned after the pattern of the original. When some of the material collected from the old nest was placed in the cage, it started at once to pick out the best fibers of chestnut and substitute these for the excelsior.

As a test of the behavior of *Neotoma pennsylvanica*, an albino rat (*Rattus norvegicus albinus*) was placed in the cage for a couple of hours. Although the attitude of the visitor was one of indifference, that of the wood rat was one of distinct hostility. On the approach of the albino, it would make a sudden charge with the forward part of its body raised, push the albino back with its front feet and then make an equally sudden retreat. This was repeated many times, accompanied usually by an opening and closing of the mouth, so that a clicking of the teeth was audible. At no time during the course of these observations was there any behavior that would indicate a tendency on the

part of the wood rat to establish amicable relations with the intruder.

The author wishes to acknowledge the valuable advice and criticism of Doctors A. M. Reese and P. D. Strausbaugh of West Virginia University.

#### Bibliography

- Brooks, A. B., 1910. The Mammals of West Virginia. Report of the West Virginia Board of Agriculture, p. 18, Dec. 30, 1910.
- Buller, A. H. R., 1920. The Red Squirrel of North America as a Mycophagist. Translations of the British Mycological Society, Vol. VI, Part IV, Sept. 22, 1920.
- English, P. F., 1923. The Dusky-footed Wood Rat (*Neotoma fuscipes*), Journal of Mammology, Vol. 4, No. 1, February, 1923.
- Goldman, E. A., 1910. Revision of the Wood Rats of the Genus *Neotoma*, Published in 1910 as North American Fauna, No. 31, p. 84, 1910.
- Howell, A. H., 1921. A Biological Survey of Alabama, North American Fauna, No. 45, pp. 53-54, 1921.
- Parks, H. E., 1923. The Genus of *Neotoma* in Santa Cruz Mountains, Journal of Mammology, Vol. 3, No. 4, pp. 241-253, 1923.
- Stone, Witmer, 1843. Description of a New Species of *Neotoma* from Pennsylvania, Proceedings of the Academy of Natural Sciences of Philadelphia, p. 16, 1893.

A PRELIMINARY REPORT OF THE SLIME MOLDS  
OF WEST VIRGINIABy FRANK A. GILBERT\*,  
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Although a flora of the State of West Virginia was published in 1913,† there is at the present time, a great need for revision and additions, especially with reference to the non-vascular plants. These are not as conspicuous as the Phanerogams and Ferns and even less is known of their distribution, probably because the difficulties of microscopic examination usually necessary for their determination, are not conducive to amateur interest.

It is the purpose of this paper to add a little to our knowledge of the Slime Molds of West Virginia, for Millspaugh reports but thirty-three species, the only rare form being *Lycogala conicum* Pers. from Hinton in Summers County. During the summer of 1928, the writer made a number of collections from Cabell County, raising the reported species to sixty-eight and more extensive work probably will double the latter number.

In the following list are given the species thus far reported from the State. The initial M after a name signifies that it was reported in Millspaugh's work, and the initial G, that it was collected by the writer and is in his herbarium.

**Ceratiomyxaceae**

*Ceratiomyxa fruticulosa* (Muell.) Macbr. (M) (G).

**Physaraceae**

- Physarum citrinum* Schum. (M).  
*Physarum globuliferum* (Bull.) Pers. (G).  
*Physarum gyrosum* Rost. (*Tilmadoche gyrocephala*) (M).  
*Physarum lateritium* (Berk. & Br.) Rost. (G).  
*Physarum melleum* (Berk. & Br.) Mass. (G).  
*Physarum nucleatum* Rex. (G).  
*Physarum nutans* Pers. (*Tilmadoche nutans*) (M) (G).  
*Physarum psittacinum* Ditm. (M).  
*Physarum pulcherrimum* Berk. & Rav. (M) (G).  
*Physarum pulcherripes* Peck. (*Physarum rufipes*) (M) (G).  
*Physarum sinuosum* (Bull.) Weinm. (M).  
*Physarum tenerum* Rex. (G).  
*Physarum viride* Pers. (*Tilmadoche viridis*) (M) (G).  
*Physarum viride* Pers. var. *incanum* Lister (G).  
*Fuligo septica* (Linn.) Gmel. (G).

\*Contribution No. 1 from the Botany Department of Marshall College.

†Millspaugh, C. F. *The Living Flora of West Virginia*, West Virginia Geological Survey, Wheeling, 1913.

- Physarella oblonga (Berk. & C.) Morg. (G).  
 Craterium leucocephalum (Pers.) Ditm. var. cylindricum Lister:  
 (G).  
 Leocarpus fragilis (Dicks.) Rost. (M) (G).  
 Diderma effusum (Schw.) Morg. (G).  
 Diderma testaceum (Schrad.) Pers. (G).  
 Diachaea leucopoda (Bull.) Rost. (M) (G).

#### Didymiaceae

- Didymium melanospermum (Pers.) Macbr. (G).  
 Didymium nigripes (Link) Fr. var. xanthopus Lister. (G).  
 Didymium squamulosum (Alb. & Schw.) Fr. (M) (G).

#### Stemonitaceae

- Stemonitis ferruginea Ehr. (M) (G).  
 Stemonitis ferruginea Ehr. var. Smithii Lister (Stemonitis Smithii)  
 (M).  
 Stemonitis fusca (Roth.) Rost. (M).  
 Stemonitis fusca (Roth.) Rost. var. rufescens Lister. (G).  
 Stemonitis pallida Wing. (G).  
 Stemonitis pallida Wing. var. carolinensis Macbr. (G).  
 Stemonitis splendens Rost. (G).  
 Stemonitis splendens Rost. var. fenestrata Rex. (G).  
 Comatricha elegans (Racib.) G. Lister. (G).  
 Comatricha nigra (Pers.) Schr. (Comatricha Friesiana.) (M).  
 Comatricha pulchella (Bab.) Rost. (G).  
 Comatricha pulchella (Bab.) Rost. var. gracilis Lister. (G).  
 Comatricha typhoides (Bull.) Rost. var. similis Lister. (G).  
 Lamproderma arcyronema Rost. (G).  
 Lamproderma violaceum (Fr.) Rost. (M).  
 Clastoderma debaryanum Blytt. (G).

#### Heterodermaceae

- Lindbladia effusa (Ehr.) Rost. (M).  
 Cribraria vulgaris Schrad. var. aurantiaca Lister. (Cribraria auran-  
 tiaca.) (M).  
 Cribraria microcapra (Schrad.) Pers. (G).  
 Cribraria tenella Schrad. var. concinna G. Lister. (G).  
 Dictydium cancellatum (Batsch.) Macbr. (G).

#### Tubulinaceae

- Tubifera ferruginosa (Batsch.) Macbr. (Tubulina cylindrica.) (M).

#### Reticulariaceae

- Enteridium Rozeanum (Rost.) Wing. (G).  
 Reticularia lycoperdon Bull. (M).

**Lycogalaceae**

- Lycogala conicum* Pers. (M).  
*Lycogala epidendrum* (Buxb.) Fr. (M) (G).  
*Lycogala flavo-fuscum* (Ehr.) Rost. (G).

**Trichiaceae**

- Trichia contorta* (Ditm.) Rost. var. *inconspicua* Lister. (G).  
*Trichia decipiens* (Pers.) Macbr. (*Trichia fallax*.) (M).  
*Trichia favoginea* (Batsch.) Pers. (*Trichia chrysosperma*.) (M) (G).  
*Trichia persimilis* Karst. (*Trichia proximella*.) (M) (G).  
*Trichia persimilis* Karst. var. *affinis* DeBary. (G).  
*Trichia scabra* Rost. (G).  
*Trichia varia* (Pers.) Rost. (G).  
*Oligonema flavidum* Peck (*Perichaena flavida*.) (M).  
*Hemitrichia clavata* (Pers.) Rost. (*Hemiarcyria clavata*) (M) (G).  
*Hemitrichia serpula* (Scop.) Rost. (G).  
*Hemitrichia vesparium* (Batsch.) Macbr. (*Hemiarcyria rubiformis*) (M) (G).

**Arcyriaceae**

- Arcyria cinerea* (Bull.) Schum. (M) (G).  
*Arcyria cinerea* (Bull.) Schum. var. *digitata* G. Lister. (G).  
*Arcyria denudata* (L.) Wett. (*Arcyria punicea*). (M) (G).  
*Arcyria nutans* (Bull.) Grev. (M).  
*Arcyria stipata* (Schw.) List. (*Hemiarcyria stipata*.) (M).

This list is preliminary to a more extensive work and does not pretend to give all of the species that may be found in the state. It will, however, be a slight contribution and may stimulate the work of others along a similar line. The writer is anxious to obtain as extensive and complete a collection of Slime Moulds as possible from West Virginia, and in order to obtain a representative number of species from various parts of the state, collectors and students are requested to send in specimens. All received will be determined and due credit given to the collector.

## RECENT TRENDS IN BIOLOGY TEACHING

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It has been said that the pathway of science is strewn with the wrecks of dead and dying theories. In other words, new facts and discoveries constantly appear which change our preconceived notions and require new adjustments. If these statements hold true for research and investigation, so should they be true of that other field in which at least ninety percent of all biologists are engaged: namely, teaching. Many in the profession today apparently get a great deal of satisfaction out of the statement that "Teaching would be a grand job if it were not for the 'd—— students.'" Be that as it may, the fact must be recognized that the "d—— students" represent the bread and butter, the apparatus, and the means which provide the saddle for us to ride our particular hobby. Nor should the fact be lost sight of that among these students are the investigators of the future on whose efforts the advancement of our particular science depends.

In view of the brilliant discoveries of Biology in the past thirty years in the field of research, it would be interesting to note what advances have been made in teaching; however, it is not the intention of this paper to attempt to make an extensive and intensive survey of the teaching field of this particular science but to present merely one or two ideas of teaching technique which seem to be changing.

When biology was first introduced into the curriculum, most of the emphasis was placed on morphology. This type of subject matter lent itself readily to drawing as a means of recording observations and aiding descriptions. Laboratory manuals were written which contained injunctions to draw in almost every alternate paragraph; drawings of everything studied in the course had to be made, not only in pencil but many times laboriously inked in. And today our heritage of drawing is still unexhausted.

The following arguments have been advanced to support laboratory drawings; first, they afford a very convenient way to record observations; in the next place, if the structures being studied are drawn, the relation and correlation of parts will be studied and observed more accurately by the student; structures seen and drawn tend to fix themselves more readily and in more detail in the mind. Finally, the training in neatness and accuracy thus acquired was good as a discipline for the student and would bring about the formation of habits which would be valuable in other courses.

Many objections have been made to drawing as a necessary part of laboratory procedure. Many students have had no previous training in drawing and maybe are not thus gifted in the slightest degree. To this group drawing is a discouraging process, an obstacle which requires

patient practice and concentrated attention to overcome. Some few students have a natural gift for sketching or may have had special training in drawing. The net result for both groups is more real study and attention to paper and pencil than to the actual specimen being studied. Instead of the real objective, the study of an organism, being emphasized, the emphasis is being placed on the method of study. True, we are agreed that drawing should not be given undue emphasis but it must be remembered that work which is most difficult receives the major interest and attention, particularly in this American educational scheme with its grades and credits. And whose laboratory work receives the highest recognition,—combat it as you will—the tendency is to allot it to the most artistic drawings.

Further, drawing is a time consuming process—a thief which steals minutes which could more profitably be spent in getting a wider acquaintance with Nature in her various forms.

In the light of what has just been said it would seem that the problem then is to find some new way of recording observations and some means of motivation for thorough and accurate observation. Some teachers advocate and are using prepared outline drawings ranging in detail from a complete, detailed drawing to merely the main outlines. These are given to students who observe in the laboratory and then color or index the appropriate drawings. New laboratory manuals are appearing with outline sketches and in some the detailed sketches are incorporated in the book. It is also possible to buy these sketches in separate sheets of the size of the usual drawing page. This has the advantage in that they can be used with any manual.

There has been much said both for and against these innovations. Miller ('28) has tried the new method of preparing drawings and his general conclusions may be thus summarized:

1. Drawing becomes a record not a study.
2. More time is available for individual conference.
3. Emphasis is placed on something other than drawing.

Contrasted to these favorable features are the following negative conclusions:

1. The new system has a tendency to teach by authority rather than original investigation. The student observes enough to complete or match his drawing and quits.

2. Student originality and initiative is stifled. If there is a difference between drawing and specimen, the specimen is wrong and the drawing is right.

His conclusion is, however, that the advantages of the new system outweigh the disadvantages.

Elliott, who observed the workings of a somewhat similar system used in a course in Embryology at a large mid-western University, reported essentially the same difficulties with use of prepared drawings

and saw no advantages. Students have been known to prepare all the drawings of the course in a week's time.

The extreme reaction against drawing has been the elimination of all drawing. This has been done at a number of universities. Emphasis is thus placed on the actual structures or microscopic sections. At varying intervals of a week or two the student is given what is known as a practical "examination."

The writer this past year, in a course in Vertebrate Anatomy, tried out a modified method of the ones previously described. Students were advised to make rough sketches of various systems for their own assistance. It was definitely understood that no grades would be given on drawings and that they were not required to draw though advised to do so. Every two weeks a conference was held and a practical examination given. The results from this procedure have been very satisfactory. More material has been covered in the course, better work has been done, and there has been more enthusiasm on the part of the student.

The writer has never seen the justification for sketches from textbooks. This has seemed to be a mere cheap substitute for real honest laboratory work, and a device for making a "pretty picture book." Aggasiz says, "Study Nature, not books;" and to this might be added, "Know the organism, not its picture." Perhaps a certain amount of drawing is necessary in morphology for the clarification of relationship but certainly there is no justification for habit sketches of plants and animals in an undergraduate Biology course.

With the emphasis on the practical examination the unconscious tendency to award better grades to the most artistic student is eliminated. All have equal chance and each is evaluated according to the amount of Biology he or she knows. This is one of the reasons for increased interest and enthusiasm on the part of the student.

The objection may be raised that it takes more time on the part of the teacher for practical examinations. On the contrary, less time is required than to grade the notebooks. Further, in preparation for such an examination the students come to the laboratory at odd times and "cram" for the test by studying and observing the actual specimens rather than committing to memory a series of sketches.

## THE STARLING IN WEST VIRGINIA

By W. M. SHARP,  
West Virginia University.

The Old World starling (*Sternus Vulgaris*) had its native home in all but some parts of Northern Europe; from this region it has been introduced into Australia, New Zealand, Tasmania and South Africa; as well as North America, in all of which places it has increased rapidly. In North America it now is found from the Atlantic coast to the Mississippi River, but within this range it is unevenly distributed.

Many early attempts were made to introduce the starling into America, but these were unsuccessful. The earliest introduction was at West Chester, Pennsylvania, before 1850, and the next at Cincinnati, Ohio, in the winter of 1872-73. John Coulson of Worcester, Massachusetts, reported having caught a few of these birds on November 8, 1876. Mr. Coulson, who was a native of England, knew the bird well, and therefore there can be no question concerning the accuracy of his identification. In May, 1889, twenty pairs were released in Portland, Oregon, but this colony did not thrive.

It is well known that the first successful introduction into America dates from April, 1890, when eighty birds were liberated in Central Park, New York City. In March of the following year eighty more were released. Within the next ten years the numerous progeny of these birds had spread northward as far up the Connecticut valley as Springfield, Massachusetts, and southward over New Jersey. At present their range extends from Nova Scotia to the Mississippi River and southward to the Gulf of Mexico.

The starling invasion of West Virginia began in the eastern panhandle counties from 1918-20 and by 1922 they had invaded almost half of the state from a northeasterly direction. By 1926 they had made a complete invasion of greater West Virginia. Many pairs, it is reported, had penetrated into the middle western states by 1926. The invasion has not been steady and even, but quite irregular, so that even now there are extensive areas in the state where the starling is unknown. In those sections where the topography is such that farming and grazing lands are rather extensive, the starling has found sufficient food and has become a permanent resident. But in other parts of a more rugged mountainous nature where food supplies are not plentiful due to the absence of agricultural lands, the starling is not found, or if present, comes merely as a transient visitor.

I made a careful study of a flock of eight starlings in the winter of 1922-23 in Pocahontas County near Marlinton, West Virginia. They were seen very often during the winter, but when spring came they disappeared. Not a starling was to be found in that region until the next winter when a flock of about eighteen appeared in the same

territory which the flock of the preceding year had occupied. They, too, remained throughout the winter, but as spring approached they divided into smaller flocks, and finally they all disappeared from the vicinity except two or three pairs that remained all summer; however, I was unable to locate any of their nests. (Since that time they have become permanent residents of this region and rear their broods here annually).

Mr. A. B. Brooks, Park Naturalist of Oglebay Park, Wheeling, West Virginia, states that starlings nested in a belfry of an old church in Buckhannon, beginning as early as 1925.

Professor Bibbie of Concord State Normal says that they began to be fairly common near Athens, West Virginia, in the years 1925 and 26. They were reported as being quite common in the vicinity of Weston in 1926. I saw several pairs and small flocks in the Ohio Valley near Huntington, West Virginia, in the spring of 1927. During my survey of the State last summer I found the starling more or less common in all the counties visited, with the exception of Boone, Logan, Lincoln, McDowell and Wyoming. In the mountainous parts of the counties bordering the above named counties the starling is also conspicuous by its absence. As explained above this is due to the absence of open pastures and extensive agricultural lands where this bird seeks its food. Mercer, Pocahontas, Pendleton and Hardy counties although mountainous support large numbers of starlings because farming and grazing are carried on extensively in these counties. At the Reymann Memorial Farm near Wardensville, Hardy County, West Virginia, the starling flocks were very numerous and of immense size. I should conjecture that there were 25,000 or more starlings in that vicinity last summer.

The first flocks that visited West Virginia were migratory, and when summer approached they went back to their northern range to nest. Observations in other parts of the eastern United States show that migration of the starling is rather generally considered a regular movement between definite summer and winter homes, but the starling even in its native habitat does not seem to have a very definitely fixed winter home. It seems quite certain that they are developing migratory habits, though they do not always settle in definite winter homes, but wander about from place to place in the southern part of their range. In the northern part they are absent or much reduced in numbers during the winter, and large flocks can be seen flying south when cold weather sets in. This migration, however, is not so pronounced as that practiced by this bird in the Old World.

The most desirable nesting places for the starling are in woodpecker holes and natural cavities in trees; these are probably its natural nesting habitations. In recent years and especially in more thickly populated vicinities, they have availed themselves of the greater security

offered by nesting in houses, farm buildings, churches, ruins, and bird houses, and there comes an occasional report that they have been found nesting on the foundations of larger birds' nests. The nest is a loose, untidy structure consisting of small twigs, straw, dried grass, leaves, wool or moss; lined with feathers. Both the male and female assist in constructing the nest. Five to seven pale bluish eggs are laid in April or May, and sometimes there is a second brood. Incubation is also shared by both sexes, and extends over a period from twelve to fourteen days. The fledglings usually leave the nest about three weeks later.

#### Economic Importance

At the present time the economic importance of these birds is quite decidedly positive. At present the birds inhabiting the state have not as yet acquired the fruit and cereal eating habits to any noticeable extent; however, there are exceptions in places where they eat cherries; but their numbers are quite small and the insect supply is so abundant that they rely largely on them for food.

A point in the starling's favor is the nature of the food brought to the nest by the parent birds during the nesting season, which covers a period of about three weeks. A volumetric analysis of the stomach contents of forty nestlings shows that injurious insects constitute 89% of the total bulk of food, neutral insects, 1.5%, earthworms and slugs, 6.5%, and miscellaneous matter, 3%. Among the insects composing this diet we find various Noctuid and Geometrid larvae, wireworms, and many Dipterous larvae, weevils and numerous small beetles. In addition to feeding the growing and rapacious nestlings upon this diet, there is every reason to suppose that during this period the parent birds also partake of a similar one.

After the nesting season the diet of the adult starling consists of insects which comprise from 42% to 60% of its entire diet. Wild fruit forms an important item for the starling, supplying more than 22% of its yearly sustenance. The starling's consumption of various wild fruits may result in a certain reduction in the food supply available for native birds. A very small percentage of apple remains has been found in the stomachs of starlings, but this condition was found to occur during February and March when the fruit eaten was mainly that left on the trees.

The blackest deed with which the starlings are charged by bird lovers is their pugnacious assaults upon the song birds. They are peaceful until the nesting season, and then they give the woodpeckers trouble by taking their nesting sites. In the spring of 1926 I took great pride in watching a pair of red-bellied woodpeckers building their nest in a Service Berry tree. (*Amelanchier Canadensis*). One day I went to the site and to my great surprise I saw a pair of starlings carrying twigs, etc., into the cavity which the woodpeckers had excavated. I

discovered broken remains of the eggs of the former occupants near the foot of the tree. They had been thrown out by the starlings.

The blue bird and the martins are the only species with which the starling is in intimate competition during the breeding season, the economic worth of which may be considered greater than that of the starling. The nests of these birds can be protected by providing nest boxes having an opening not greater than  $1\frac{1}{2}$  inches in diameter, large enough to admit the blue bird or martin but too small to accommodate the starling.

#### Future West Virginia

If the starling multiplies in the future in proportion to the present rate of increase, within the next ten or twenty years we shall be facing the same serious problem that confronts the farmers in England and Australia. It is difficult to estimate the number of starlings in West Virginia, but 50,000 pairs would certainly be the minimum population for the spring of 1929. If each pair should rear three pairs of young, the progeny and parents in a single year would total 400,000 individuals. At the same rate of increase the number in 1930 would be 1,600,000; in 1931, 6,400,000; and at the end of 1932 the total population would be 25,600,000. These figures are mentioned merely to give some idea of the prolific nature of these birds, with no intention on the part of the writer to predict that such an enormous population will actually be produced in so short a time. Natural enemies and unfavorable factors will of course tend to check this rate of increase so that no such starling host need be anticipated. However, these figures are calculated on the basis of a single brood per year, although in many parts of the state two broods are reared. We do know that throughout our state the number of these birds is increasing rapidly and from this we may conclude that in time, as a consequence of this increase, these birds instead of being beneficial agents will soon become a positive nuisance by reason of their attack on the crops of the garden, orchard and field, to secure the food necessary for the maintenance of such large numbers.

Reports of the British Government of the introduction of the starling in Australia read as follows: "When the starlings were first introduced into Australia it was generally regarded as one of the most beneficial birds to the agriculturist and fruit grower." We can now say the same thing in the United States, but if the starlings become much more numerous, as is sure to be the case, we may find the further wording of this report to be true also of the changed conditions here at home. "But with its rapid increase a marked change took place in its food habits to such an extent that in 1905 Mr. French, the Victorian Government entomologist, wrote, 'there can be no doubt about the starling being a most pernicious enemy to the fruit growers and viti-

culturist in this state. The starlings are increasing a thousand times faster than their natural food supply, hence they must avail themselves of such as is obtainable. Once driven to this, an appetite is acquired, and fruit diet being easily obtained, they will not seek any other, even if available. It is pleasing to note that the Shire Councils are offering a bonus for starling's heads and eggs. Valuable insect eating birds such as diamond-birds, tree creepers, and tree swallows are being driven out of their nesting places in hollow trees by swarms of starlings, and before long these insectivorous birds, useful to the farmer and orchardist, will be driven out of the state.' "

There is a possibility that the number of starlings may increase to such a degree that these birds will be forced to prey upon our field and orchard crops and in doing so they may become detrimental to the farmer's interests. In other words, we shall have too many individuals of one species requiring the same kind of food within a limited area, and this is the case in nearly all instances where mammals, birds and insects become detrimental.

PROCEEDINGS OF THE  
ANIMAL PHYLOGENYBy W. I. UTTERBACK,  
Professor of Zoology, Marshall College.

(Book Review)

This is a review of *Animal Evolution*\* as recently published by the noted biologist of Smithsonian Institution, Dr. Austin H. Clark, whose many years of exhaustive research, especially among the humbler groups, has led him to a declaration more in favor of Creationism than that of gradual, selective Evolution.

Clark's view is that the Animal Phylogeny consists of a progressive series of specially created phyla, but without a distinct evolution of one phylum directly into another.

In a prior copyrighted pamphlet\*\* I had also published a similar view on Special Creation and from the reaction of my publication, after a wide distribution, and also from the criticism of Clark's publication, as seen in the press, a swing in the direction of Creationism is noted among the leaders in the modern trend of thought.

However, this gesture does not mean a surrender of the generally accepted theory of evolution, especially as observed within the animal phyla, but does indicate an acceptance of Clark's views as more of an amendment or modification of previous theories.

The idea of our Smithsonian biologist is that the inorganic world is not to be divorced from the organic, as has been the error of both the strict Creationists and the severe Evolutionists, and that all organic forms may be interpreted as falling under the same systems of crystallization as is characteristic of inorganic matter.

On this basis Dr. Clark has conceived of an intermittent evolution with radial symmetry for the simpler forms and bilateral symmetry for the more complex types of animals; with wide, unbridged gaps for the major groups and with the appearance of the phyla as mutations without any appreciative changes thereafter, except for the variations within these major groups as happened best to meet the conditions of the time.

Through the most ingenious cyclic Scheme, showing the various types of correlating structure of the various forms of the Animal Phylogeny, Clark has built up such a new harmonizing system of taxonomy that animal groups, formerly considered of uncertain relationship, now settle into a more definite and fixed classification.

\*The Quarterly Review of Biology, Vol III, No. 4, Dec. 1928, pp. 523-529.

\*\*The Great Life Cycle, published by the Author of this paper Nov. 27, 1928, and reviewed in The Quarterly Review of Biology, Vol. IV, No. 2, June 1929. This is essentially the view held by Agassiz. Ed. Com.

## CHANGES IN THE SUPRARENAL GLAND IN VITAMIN-A DEFICIENT RATS

By HAZEL C. CAMERON,  
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## (Abstract)

The most significant finding in the suprarenal glands of a small preliminary series of young white rats kept on a Vitamin-A free diet, is in the water content of the gland, which at the period of constant body weight just preceding the decline of body weight, shows a lower value than do normal control rats at the same age, but with a steady increase from this point to a value above the normal, followed by a decline to the death of the animal. This increase in the water content of the suprarenal gland comes at the period of declining body weight in the A-deficient animals, and coincides with the time of appearance of the infections of the middle ear and glands about the mouth found in animals on Vitamin-A free diets. It coincides also with the time of appearance of the xerophthalmia characteristic of this vitamin deficiency, which according to the observations of Mori and others, is characterized by marked keratinization and other epithelial changes, in both the eye itself and the parocular gland, accompanied by or caused by a drying up of the normal secretions. This occurrence of the infections of the middle ear, in the rat, and glands about the mouth, and of xerophthalmia at the time when the water content of the suprarenal gland is rising to its highest value, and not at its period of dehydration, seems to conform to the observation of Carlson and Hoelzel recently, that colds occur at a period of increasing hydration, rather than during dehydration, as in fasting; and points to a possible explanation of the "infection preventing" function of Vitamin-A. The water content of the suprarenal gland in normal rats is fairly constant, showing in the series studied, only a slight decline at eight weeks (the lowest value for the A-deficient animals) and a slight increase for the succeeding weeks—a variation which may disappear with greater numbers of animals. A small series of older rats, both A-deficient and normal controls, show the same relationship in the water content of the suprarenals.

The water content of the thyroid gland in the same Vitamin-A deficient animals parallels very closely that of the normal controls, but at a higher level and bears no relation to the curve for the water content of the suprarenal. This would seem to indicate that the decline in body weight of the A-deficient animals is not responsible for the character of the curve for water content of the suprarenal gland.

Changes in the total weight of the suprarenal glands of the Vitamin-A deficient rats studied, as compared with normals, do not warrant a conclusion, since the individual variations are greater than any group

difference. It is noteworthy, however, that contrary to the observation of J. C. Donalson on the rat and of Kellaway for the guinea pig, the left gland is larger than the right in only about 50% of the cases studied, and sex differences, in the size of the suprarenals, if present, are too small to be observed in this small series of animals. In the case of the thyroid, however, the male gland was in all cases heavier than the female, in both A-deficient and control animals, the control animals having slightly larger thyroid than the Vitamin deficient.

SOME COLOR REACTIONS OF ALDEHYDES, KETONES,  
QUINONES AND OXIMES WITH COMPOUNDS WHICH  
CONTAIN ACTIVE METHYLENE GROUPS\*

By L. P. HANSEN,  
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(Abstract)

Color reaction studies made by Remo de Fazi† and by Luis Guglielmelli and Angeles Delmon‡ on aldehydes and on some carbohydrates suggested the idea of carrying out a series of tests on a somewhat broader scale than was done by the experimenters named above.

Tests were carried out with a series of compounds, each of which had one or more methylene groups ( $-\text{CH}_2-$ ), on a series of aldehydes, ketones, diketones and ketone derivatives.

The compounds with the methylene group were of four different types. (1) A methylene group ( $-\text{CH}_2-$ ) in which the carbon is linked to one or two other carbons which form an integral part of an aromatic complex. Example: acenaphthene. (2) A methylene group in which the carbon is linked on the one hand to a carbonyl carbon and on the other either to hydrogen or another carbonyl carbon or another methylene carbon or to a carbon which is part of an aromatic complex. Example: acetone, acetylacetone, cyclohexanone and acenaphthenone. (3) A methylene group in which the methylene carbon is linked to two carboxyl carbons, either in the form of the acid or of an ester. Examples: malonic acid and diethyl malonate. (4) A methylene group in which the methylene carbon is linked on the one hand to a carbonyl carbon and on the other hand to an amide nitrogen. Example: hydantoin and diketopiperazine.

The methylene compounds used were the following: acenaphthene, fluorene, acenaphthenone, acetophenone, acetone, ethyl acetoacetate, acetylacetone, cyclohexanone, phloroglucinol, diethyl malonate, malonic acid, hydantoin and diketopiperazine.

The aldehydes consisted of a series of aromatic aldehydes and a few aliphatic aldehydes. They were the following: paraldehyde, acetaldehyde-sodium bisulfite (contact at the interface between sulfuric acid and the alcohol solution of the reactants liberates acetaldehyde from paraldehyde and acetaldehyde sodium bisulfite), citronal, cotronellal,

\* Presented at the Sixth Annual Meeting of the West Virginia Academy of Science at Charleston, April 26-27, 1929.

† Remo de Fazi, *Gazz. chim. ital.*, 46 I, 334-59 (1916).

C. A. 11, 1144-1146 (1917).

Remo de Fazi, *Gazz. chim. ital.*, 54, 658-657 (1924).

C. A. 19, 821

‡ Luis Guglielmelli and Angeles Delmon, *Anales Soc. Quim. Argentina*, 5, 169-176 (1917).

C. A. 12, 1185 (1918).

furfural, p-tolualdehyde, salicylaldehyde (o-hydroxy benzaldehyde), p-hydroxy benzaldehyde, anisal, vanillin, piperonal, cinnamic aldehyde.

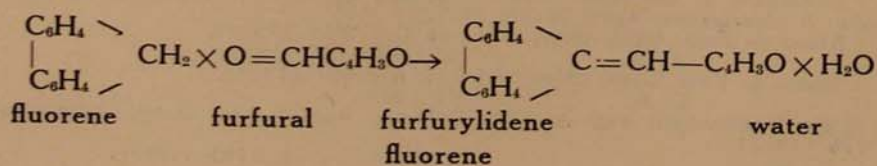
The following ketones and ketone derivatives were used: acetone, acetone sodium bisulfite, ethyl acetoacetate, dibenzal-acetone, cyclohexanone, phloroglucinol, acetophenone, benzophenone, fluorenone, pyruvic acid, benzil, 1-4 benzoquinone, beta-naphthoquinone, anthraquinone, acenaphthenequinone, isatin, quercetin, quercitrin, fluorenoneoxime, phenanthrenequinone monoxime.

The tests reported in this paper were of an entirely qualitative nature. Solutions or suspensions of all the substances were made to definitely determined concentrations in absolute alcohol at ordinary laboratory temperature. The concentration of the substances used was not uniformly the same. Almost all of the solids were carefully made up to a concentration of 0.04 M. The concentration of the liquids were uniformly somewhat higher, varying from about 0.1-0.4 M. In such cases where all of the substance in the alcohol failed to go into solution, the tests were made with solutions containing some of the material suspended in the solvent.

The procedure for the tests was as follows: One half c. c. of a solution of one of the methylene compounds was pipetted into a test tube. To this was added one c.c. of a solution of an aldehyde, ketone or ketone derivative. For the controls the volume was made up to 1.5 c.c. with an absolute alcohol. Then one c.c. of concentrated sulfuric acid was carefully added with a pipette in such a manner that there was a minimum amount of mixing of the acid with the alcohol solution. At the interface between the sulfuric acid and the alcohol solution a color test was indicated by the appearance of a color more or less intense and of varying tints, depending on the kinds of substances in solution. It was considered as a positive test when the color was distinctly different from the colors obtained in control tests on the reactants separately, which were carried out along with the tests on the mixture of the reactants.

In general, positive tests were obtained with the methylene compounds from the groups 1 and 2 on the aldehydes, and negative results were obtained with all of the methylene compounds on all of the ketones. These two statements cannot be considered as absolute rules, since some exceptions occurred in both cases.

The reaction taking place between the aldehyde or ketone and the methylene compound is essentially a condensation type of reaction. Example: fluorene and furfural:



De Fazi assumed that the production of a distinctive color test is due to the formation of the condensation product (in the case cited above, furfur ylidene fluorene).

De Fazi's contention that the methylene compounds acenaphthene and fluorene may be used to distinguish cyclic aliphatic and aromatic aldehyde from straight chain aliphatic aldehydes does not appear to be a rule that can be followed without qualifications. The tests referred to above show that an active straight chain aldehyde and a ketone may show almost identical color tests. Example: Paraldehyde, benzaldehyde and pyruvic acid gave identical color reaction tests with acenaphthene by the above method. Other ketonic groups also gave strong positive color reactions.

Further qualitative tests will be made on a series of carbohydrates and sensibility tests by maximum dilutions will be made on all these mixtures which gave positive reactions in qualitative tests.

QUANTITATIVE STUDIES ON SOME SOURCES OF  
ERRORS INVOLVED IN THE MUNSON  
WALKER METHOD\*

By L. P. HANSEN,  
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(Abstract)

The purpose of this study was to discover the error involved in the use of the Munson-Walker method in carbohydrate determinations, with special reference to the effect of washing asbestos mats in Gooch crucibles,

- (1) with water at different temperatures,
- (2) with rochelle salt and sodium hydroxide solution of the same concentration as used in standard Fehling's solution.
- (3) with sodium hydroxide solution as in (2) but without the rochelle salt,
- (4) with copper sulfate solution of the same concentration as used in the copper sulfate portion of standard Fehling's solution,
- (5) with standard Fehling's solution, 25 c.c. of each portion and diluted to 100 c.c. with distilled water,
- (6) on varying but definitely known amounts of cuprous oxide had been collected, with water at different temperatures,
- (7) on which varying but definitely known amounts of cuprous oxide had been collected, with standard Fehling's solution, 25 c.c. of each portion and diluted to 100 c.c. with distilled water.

A long fibrous asbestos was used in these studies. It was prepared in the following manner: first digested with hydrochloric acid (1-3) for several days, then digested with a 2½% sodium hydroxide solution for a similar period, followed by digestion with a mixture of sodium hydroxide and rochelle salt solution of the same concentration as used in Fehling's solution, followed by digestion with nitric acid (1-3), then thoroughly washed with distilled water, and finally held in suspension in distilled water.

Under (2) the asbestos used was treated slightly differently. The third step in the preparation, i. e. the digestion with the rochelle salt-sodium hydroxide solution was omitted.

Summary of Results—(1) The effect of washing the asbestos mats with water at different temperatures is not significant.

(2) the asbestos mats sustained a very significant loss on first treatment with the sodium hydroxide-rochelle salt-solution. In a second

\*Presented at the Sixth Annual Meeting of the West Virginia Academy of Science at Charleston, W. Va., April 26-27, 1929.

treatment the loss is much smaller, but still significant. A third treatment results in a loss which is no longer significant.

(3) The asbestos mats show a significant loss on washing with sodium hydroxide solution or with a rochelle-salt-sodium hydroxide solution (as under (2)), the loss being slightly larger with the sodium hydroxide solution alone. In both cases the loss was approximately of the same amount as in the second treatment cited under (2). For the preparation of asbestos this suggests two consecutive digestions with sodium hydroxide solution as preferable to the digestion with sodium hydroxide solution followed by digestion with rochelle salt-sodium hydroxide solution.

(4) The washing of asbestos mats with a copper sulfate solution shows a slight absorption of copper sulfate, verified by an increase in weight of the crucibles and by the color of the mats subsequent to the treatment.

(5) In several groups of crucibles which were washed with standard Fehling's solution unexpected gains in weight occurred. These gains were fairly consistent, but no satisfactory explanation seems at hand. On the whole, however, it seems fair to conclude that the treatment resulted in a slight loss in weight, varying on an average from 0.0001 to 0.0003 gram. Treatment with Fehling's solution which has been boiled two minutes—as is always done in sugar determination by the Munson Walker method—suggests a small amount of self reduction.

(6) Washing cuprous oxide on asbestos mats with water at different temperatures shows that the solvent effect of water on cuprous oxide increases as the temperature of the water used is raised. Above 65°C. the loss of the amount of cuprous oxide is significant. It is safe to wash with water at 60° C.

(7) Washing cuprous oxide on asbestos mats with Fehling's solution brought just to boiling indicates that a significant loss occurs. The amount of the loss is apparently not dependent on the amount of the cuprous oxide on the mat. If the mats are used repeatedly without removing the cuprous oxide, losses amounting to an average of from 0.0005 to 0.0010 gram may be expected even when water at 60°C is used for washing.

## ARSENIC, A FRIEND AND ENEMY OF MAN

By E. B. KESTER, Charleston, W. Va.

The acquaintanceship of arsenic, the most sinister of the elements, with the human family began in the fifth century B. C. when it was known to the Greeks in the form of the native sulfides, orpiment and realgar. The early alchemists, attracted by the golden color of orpiment, began looking to this material as a key to the philosopher's stone that would open the door to immeasurable riches. Emperor Caligula in the first century A. D. had large quantities of it melted down with orders for the gold to be extracted. History does not tell the result of this metallurgical operation, but we have reason to infer it was unsuccessful.

Arsenic containing materials were early recognized as having medicinal properties and came into wide use as external remedies for ulcers and related disorders.

Coincident with the employment of arsenic for the restoration of health came also its use as a poison by malefactors, out of personal spite, enmity or political ambition. White arsenic, first made by Geber, an Arabic alchemist in the eighth century by heating the sulfide, offered advantages over all other poisons then known, for the reason that it was practically tasteless and could not be readily detected by the unfortunate victim in his food and drink.

In India there are records of a "strange woman" who appeared at intervals in the bazaars, passing out sweetmeats heavily drugged with arsenic to those with whom she came into conversation. The rationale in this case has never been ascertained since the victims were apparently picked indiscriminately, but was most probably an unmotivated homicidal mania. It may be inferred, however, that one of murderous intent might be unscrupulous enough to wipe out a score of innocents to make sure of getting his man.

It is in the fifteenth century that the deeds of the poisoners began to be linked with the political history of Europe. You will recall the notorious Borgias, of whom Pope Alexander VI was the first, an evil pontiff who made cunning use of poison to rid himself of enemies churchly or temporal, but who finally died by his own hand through a miscarriage of a poison plot. Then, there were Cesare and Lucrezia Borgia, both of whom have been described as poisoners on a wholesale scale. There has been some cloud cast on the stories regarding Lucrezia, but there is no doubt her brother, Cesare, was a blackguard and degenerate of the worst type. Cesare used both a solid and a liquid poison. The solid contained crude phosphorus, white arsenic and a basic salt of copper. For preparing the liquid, a wild bear was caught, fed an enormous dose of arsenic, and when his convulsions began, strung up by the heels, head down. During his death struggles, a

deadly and venomous discharge issued from his nose and throat that was carefully collected and preserved against future use.

It is understandable that those in high places frequently found it inconvenient to do the actual poisoning themselves, for the act required a procedure likely to throw them under suspicion. Hence, arose a class of professional poisoners who developed the strategy and technique of poisoning to a high degree. The Venetian school was the first. Employment was plentiful. The worth of the poisoner was gauged by his subtlety in carrying out the deed so that the intent of murder was not discernible. Nor was his social status in any wise impaired. Unlike—shall we say a gunman in Chicago—he was a man in good standing. Certain of the Italian states used them steadily against emperors, princes and powerful nobles. The deed was authorized in council proceedings, entrusted to a prisoner, and when accomplished, the notation "factum" entered in the margin of the records. John Ragusa, a Franciscan monk, had a definite scale of prices: The Great Sultan, 500 ducats; King of Spain, 150 ducats; Marquis of Mantua, 50 ducats; Duke of Milan, 60 ducats; the Pope, 100 ducats. As you see, the despatching of a mere pope did not bring a fee at all comparable to that involved in the case of royalty.

Then, there was the great Roman school of poisoners, which existed from the sixteenth to early eighteenth centuries and reached such proportions that high and low degree alike lived continually in mortal terror. It was an era of plots and counter-plots, secret formulae never written but handed down from father to son, elaborate technique in the execution of murder by poison. In 1569 there was unearthed a secret society of women in Rome who were conspiring to poison their husbands. A noted poisoner of this period was Toffana, a woman who accounted for more than six hundred victims. She put out a beauty preparation called "Aqua Toffana," containing arsenic that could be used by the innocent for a skin treatment or by those "in on the know" against their enemies or rivals.

A word regarding methods of administration of arsenic for poisoning purposes: wines, medicines, beverages of all kinds have been used widely. Belot, in the seventeenth century, crammed a toad with arsenic, placed it in a silver dish, pricked its head and crushed it during the recital of incantations. This, he declared, made the vessel poisonous to all wines poured therein even after repeated washings.

Clothing, boots, gloves and shirts have been impregnated with arsenic. The wearer, soon or later, acquired a dermatitis sufficient to confine him to his bed where he could be disposed of at will through his medicines or food.

There are in existence rings with envenomed points that at one time enjoyed a wide vogue as a poisoning medium.

The singular case is on record of a person who acquired arsenical poisoning from a mattress containing arsenic in quantity.

Food and chewing gum have been favorite methods of administering arsenic. King John of England in the sixteenth century poisoned the bewitching Maude Fitzwalter with an egg.

Pope Clement VII is said to have died from arsenical poisoning by inhaling arsenious vapors from a torch in a religious procession. One would not call this a sure-fire method for general use, but the case of Leopold I, Emperor of Austria is somewhat comparable. On being seized with a chronic illness, this ruler indulged the fear that one of his enemies was poisoning him. To justify this suspicion, however, was a more difficult matter since his family and imperial associates were eating at the same table, drinking of the same wine and not suffering his symptoms. Borri, his physician, was summoned to his bedside and immediately sniffed the air suspiciously. "Yes, your Majesty, you are being poisoned," said he, "not by your food, not by your wine, but by the air you breathe." The candle flames, he pointed out, were ghostly white and above them was a definite incrustation on the ceiling. The wicks proved to be heavily loaded with white arsenic.

From a fairly recent medical encyclopedia it is to be learned that arsenical poisoning in its acute form may be felt immediately or after any period of time up to sixteen hours. The fatal period ranges from twenty minutes to twenty days. The symptoms are nausea, vomiting, intense thirst, abdominal pains, cramps in the extremities, severe headache, cold skin, clammy perspiration, painful respiration and irregular pulse. Death by arsenical poisoning is not a pleasant pastime, and may result from as small a dose as two grains of white arsenic.

When the knowledge that poisons were being employed as a lethal weapon became current, naturally there came into being defensive measures against them both for preventive purposes and as antidotes. The ancients, always seeking the universal remedy, used a kind of red earth called terra sigillata which consisted in the main of oxides and silicates of iron, aluminum and magnesium. There was probably some virtue in this stuff since it persisted as a remedy through the sixteenth century.

The horn of the unicorn (tusk of the narwal) was believed by the credulous to possess great value as an antidote to any poison if a small fragment was placed within the wine glass. The benzoar stone, formed in the bodies of certain animals, especially swine, was thought to be infallible, although we now know its composition to be principally calcium phosphate.

Then there were various theriacas, elaborate brews that remind one of the witches' scene in "Macbeth." The number of ingredients in any one of them would make the average cough syrup feel foolish. That of Mithridates in the second century B. C. contained fifty-four ingredients. That of Philon of Tarsus in the first century A. D. survived

seventeen centuries passing into many of the early European pharmacopeias. It remained in that of London up to 1746, though somewhat modified. In its original form it contained such curious items as "the red hair of a lad whose blood has been shed on the field of Mercury." Its later modification contained opium, pepper, ginger, caraway, syrup, honey and wine.

The theriaca of Andromachus, first century A. D., was essentially that of Mithridates with the addition of vipers. It was claimed to counteract all poisons, bites of venomous animals, relieve pain, weakness of stomach, asthma, difficulty of breathing, phthisic, colic, jaundice, dropsy, weakness of sight, inflammation of the kidneys and bladder and plague.

That of Democrates contained two hundred and fifty substances including dried vipers, pearls, red coral and emerald. It was included in the London pharmacopeia of 1618 and was an official remedy until 1746.

That of Venice contained sixty-one ingredients, and was also included in the early London pharmacopeias until 1746. It was prepared with elaborate ceremonials under the direction of medical professors.

I wish to call your attention to the element of mysticism that prevailed all down through these unenlightened ages in the preparation of poisons or their antidotes. The recital of incantations, or charms, or magic words, the ritual, the costumery, the motions and mystical signs were as important as the ingredients themselves.

In modern superstitions, like the rabbit's foot, we find a relic of the wide use of charms and amulets through the ages to ward off poisons. It was in answer to the idea that poisons had a magnetic attraction for each other. During the Great Plague of London, amulets containing arsenic found a ready sale, for it was believed that they would preserve the wearer from infection.

When chemical composition became more exactly known and chemical laws more thoroughly understood, we find arsenical poisoning counteracted more logically and practically. Hydrogen sulfide has been used to precipitate the arsenic as an insoluble sulfide, though this is not so effective as hydrated oxide of iron or sodium thiosulfate. I read an interesting case of a young man who had been disappointed in love. Not finding life worth living, he went to the nearest drug store, demanded a quarter's worth of white arsenic, rushed home with his package and downed the contents immediately. Unluckily for him, he straightway informed his family of his rash act and was rushed to the nearest hospital for treatment before the action of the arsenic would set in. It happened the case was given to two young interns very unskilled in such matters who proceeded to alternate huge doses of hydrated oxide of iron with the stomach pump a little too often. As a result of their vigorous measures, the young man died. When it came to the inquest, the druggist declared he had given his customer cream of tartar to avoid

being party to a suicide. Arsenic, on the other hand, was found in quantity in the stomach contents of the deceased. The internes were questioned and finally confessed that in their terror over causing the man's death, they had put some arsenic in the stomach to make it look good.

Chronic arsenical poisoning is frequently experienced in a variety of industries such as the manufacture of white arsenic, arsenical pigments and arsenical medicinals. Paperhangers have acquired it and workmen in dyeing establishments where sodium arsenate has been used as a mordant have been known to become infected. Arsenic is rapidly absorbed and distributed by the body and after death may be found in all the organs. The liver usually contains the largest amount, but the kidneys also absorb considerable quantities.

Progress in the chemistry of arsenic began in 1772 when Scheele discovered arsenic acid and isolated metallic arsenic. But this post-dated Cadet's fuming arsenical liquid which was made in 1760 by distilling anhydrous potassium acetate and arsenic trioxide.

This terrible, poisonous and nauseating liquid was the subject of investigation by such chemical lights as Berzelius, Dumas, Laurent and Gerhardt, but it remained for Robert Bunsen to establish the formula of cacodyl in 1837 and work out the cacodyl series. It will be remembered that Bunsen lost an eye from an explosion while preparing cacodyl cyanide. Additional researches on cacodyl compounds were carried out by Baeyer.

In 1859 et seq. Cahours and also Hofman concerned themselves with the preparation of arsonium compounds, comparable to ammonium compounds. Cahours obtained arsenic pentamethyl, the only compound of its kind ever synthesized.

Eighteen sixty-three marks the discovery of arsanilic acid by Bechamp who assumed that it was an anilide similar to acetanilide having the formula  $C_6H_5NHA_sO_3H_2$ .

In 1875 Michaelis began a systematic synthesis of a wide number of types of organic arsenicals and in 1881 made the first arseno compound, arsenobenzene,  $C_6H_5As=AsC_6H_5$  by reducing phenyl arsine oxide with phosphorous acid.

Coming down to more modern times still, I should like to dwell a little while on the subject of Ehrlich who has done more to establish therapeutic arsenicals on a sound basis than any one man, and the steps by which he elaborated his famous Salvarsan, Arsphenamine, Arsenobillon, or colloquially, "606." In 1903 Laveran discovered that while arsenic trioxide killed parasites in the test tube, it did not do so in the human body. The same year Ehrlich concluded from an investigation of arsanilic acid, the sodium salt of which is called Atoxyl, that it had no parasiticidal value. In 1905 and 1906, however, papers by Breinl and Kinghorn and by Thomas asserted that Atoxyl had therapeutic

possibilities, which caused Ehrlich to resume his studies on it. Incidentally, he found the true structure of arsanilic acid to be  $\text{AsO}_3\text{H}_2\text{C}_6\text{H}_4\text{NH}_2$  by finding it could be diazotized and coupled to form dyes. By acetylating he obtained acetylarsanilic acid, Arsacetin, that was less toxic than Atoxyl itself. Both these compounds, he observed, had few trypanocidal properties in the test tube although they were markedly trypanocidal in the animal organism. This fact led him to assume that certain alterations of the molecular structure by some chemical action was responsible for their heightened activity, and assumed it to be due to the reducing power of the tissues on the arseno group. Then began his preparation of arseno compounds. Here, he needed alkali-solubilizing groups so that the compounds could be put into solution as neutral salts. Arsenophenylglycine,  $\text{HOOCCH}_2\text{NHC}_6\text{H}_4\text{As} = \text{AsC}_6\text{H}_4\text{NHCH}_2\text{COOH}$  was synthesized, and while it proved extraordinarily efficacious in rabbit syphilis, was found to be unfitted for use in human syphilis.

In some previous work Ehrlich had done on the trypanocidal properties of azo dyes, he had observed the favorable influence of ortho hydroxy and amino groups, and it is this happy combination that is characteristic of Salvarsan and all the Salvarsan derivatives. Salvarsan was his six hundred and sixth compound. While remarkably effective against syphilitic infections, Ehrlich knew it had disadvantages. Its most stable form is its hydrochloride salt, but a solution of this is far too acid for injection and must be treated with enough caustic soda to form the sodium salt. Accordingly, Ehrlich began casting around for another compound or derivative of Salvarsan that could be sold in the dry form, but which would dissolve to form a neutral aqueous solution. Eventually, he arrived at his Series No. 914, Neosalvarsan, which is the sodium salt of the formaldehydesulfoxylic acid derivative of Salvarsan itself. A number of other Salvarsan compounds are now available, Sulfosalvarsan, silver Salvarsan, Luargol, and some of the coordination compounds of Salvarsan with salts of heavy metals.

In closing I wish to list the uses of arsenic beginning with its inorganic compounds. First, are its medical uses. We find arsenic effective in progressive pernicious anemia where iron is futile; for scaly skin diseases like psoriasis; for modification of nervous functions to abate pain, spasm and undue reflex irritability as in gastric irritability, asthma, coryza (except in hay fever caused by pollen); chorea and neuralgia; for malarial infections second only to the cinchona alkaloids. In fact it succeeds sometimes when quinine fails. It is administered as white arsenic, arsenic triiodide, Fowler's solution and sodium arsenate.

In Styria, a province of southern post-war Austria, the peasants have become addicted to the habit of eating arsenic, the women to beautify their complexion, the men to increase their endurance in carrying heavy loads. That it actually brings about these results is well established. To discontinue the use of it causes a rapid decline in their

physical well-being. It is fed to their horses, who develop sleek, glossy coats and heavy bones. Strangely enough, in other countries where arsenic eating has been tried, the attempt has invariably resulted in failure. I suppose in Styria high tolerance to arsenic has been developed through many generations of arsenic eaters.

As insecticides, the calcium, lead and copper salts of arsenic acid rank high. Sodium arsenate is used as a mordant in dyeing. The yellow sulfide of arsenic is an excellent pigment and a mixture of arsenic sulfides called ruby sulfur has a place in pyrotechnics as the essential ingredient of white fire.

In the field of organic arsenicals, of medicinal value are the cacodylates in skin diseases, malaria and secondary anemias; Salvarsan and its related compounds in the treatment of syphilis; Stovarsol, 3-acetamino-4-hydroxyphenylarsonic acid in dysentery.

The remarkable compound Tryparsamide, p-arsonophenylglycineamide was developed at the Rockefeller Institute. It is finding wide use in Trypanosomiasis and Paresis.

Still another arsenical of importance is one more recently developed, Etharsanol, p-arsonophenylaminoethanol, which experimental results have shown to be a strong therapeutic agent in Trypanosomiasis.

Of the organic arsenicals used for non-medicinal purposes there are several: Lewisite, beta-chlorovinylchloroarsine is a powerful mustard gas; diphenylchloroarsine was widely used in the war as a sneeze gas; chlorovinylarsineoxide has been found by the Chemical Warfare service to be an efficient protective agent for marine piling.

For the future of arsenic, and in particular, the chemotherapy of organic arsenicals, I predict great strides. The relatively few compounds employed having proved extraordinarily effective in combatting pathogenic micro-organisms, I see no reason why this use may not be extended many fold. The difficulties, however, in finding an appropriate arsenical for a specific purpose are enormous. Its effect on the host is quite as important as its effect on the organism, and the proper balance is mainly to be sought in the form of a proper organic nucleus. The closest kind of co-operative work is essential between the organic chemist and pharmacologist to obtain a material with a high lethal dose, a low curative dose, and one that leaves the patient without pernicious after effects such as nervous disorders.

## THE IMPORTANCE OF ANALYTICAL TECHNIQUE

By W. C. WELTMAN, Charleston, W. Va.

Analytical Chemistry in its modern form started with Lavoisier. He brought to chemistry what it most needed—the viewpoint of the physicist, exact measurements. By his use of the analytical balance and his actual weighings, of reaction products, he dealt the death blow to the Phlogiston theory and founded modern chemistry.

Berzelius by his painstaking work on atomic weights and combining weights founded the science of quantitative analysis. After him came Liebig who among other contributions to chemistry, developed the method of organic combustions almost in its present form, simplified it so much that he boasted that any intelligent monkey should be able to conduct it successfully. Then the list becomes too long to enumerate here. Practically every great chemist of the nineteenth century made some contribution to analytical chemistry. Many of the methods still in use today in our laboratories bear the names of eminent chemists of the nineteenth century. With the development of the coal tar industry came the rise of synthetic organic chemistry, and analytical chemistry was more or less relegated to the background.

In using the methods of quantitative chemistry, methods which have been so refined and simplified that we can teach a boy with a grammar school education and with no knowledge of chemistry to perform them, we are prone to forget the laborious and painstaking work which went into their development. Today, in industrial chemistry which is producing in carload lots the laboratory curiosities of yesterday, new analytical problems are continually arising. To meet these problems there must be chemists trained in analytical technique.

Analytical chemistry is vital to all fields of chemistry whatever the basis upon which it is divided. In the field of organic synthesis, for instance, analysis precedes and accompanies the synthesis. All the natural products which are now made synthetically had first to be analysed, and their structure and composition determined before it was possible even to begin the synthesis. In industry the analytical chemist properly called the control chemist, controls every step of the process from testing the raw materials to final tests on the finished product.

There is nothing spectacular about the work of the analytical chemist. He makes no new products, establishes no new industries, although sometimes he may reestablish a failing industry, which is going on the rocks due to changes in raw materials or changes in requirements which cannot be met by the old rule of thumb methods. Analytical technique seeks to improve methods of analysis, either shortening the time interval between the taking of the sample and the report, or in increasing accuracy; to develop new methods for new products as occasion arises; to adapt the results of research to plant production; to

supervise processes in chemical manufacturing by chemical control; to devise means of improving product; to shorten time required for manufacture; to combat corrosion; this list may be extended indefinitely.

There is a vital difference in analytical and research procedure in that a time factor enters into the latter. The research chemist is assigned a problem and then as the first step familiarizes himself with all the literature dealing with the subject. Then he goes to work and in a few weeks or months he may begin to get results. The analytical chemist does not have this time. When something goes wrong in the plant and orders are piling up, he has to discover the cause and remedy it, usually before he can quit work for the day. It is a different type of mind and a different attitude which must be brought to bear upon control work than upon research. The two requisites of analytical work are accuracy and speed. One is as important as the other and they usually go hand in hand. The rapid worker is the accurate worker if his mind is as nimble as his hands. There is no place in the control laboratory for the man who can do only one thing at a time. A good chemist can do several things at a time. He plans his work so that the several operations of digestion, filtering, ignition, combustion, etc., can all go forward together and starts operation involving long periods of digestion or settling, first. The man who prides himself upon being careful, slow, and accurate is simply lazy.

Analytical technique is the art of doing analytical work. Its principles are carried out throughout the entire procedure. The analysis is done by the most suitable, accurate, rapid and elegant method. This involves the choice of gravimetric, volumetric or colorimetric methods, proper size of sample, proper accuracy in weighing. For instance if we are using, say, a two gram sample and calculate the results on a fifteen inch slide rule, it is waste of time to weigh to the fourth decimal of a gram. If the analysis involves titration the size of sample and strength of solution should be so gauged that the burette will not need to be refilled. Carried to the logical conclusion, analytical technique prescribes the proper size and grade of filter paper, size of beaker, crucibles. Once these factors have all been determined by the analytical chemist for any given method, it can be turned over to the beaker boy or the aforementioned intelligent monkey, and the chemist is then free to devote his time to other problems, and merely supervise the work which has now become routine. This supervision is always necessary where non-chemists do chemical work. The simpler methods can easily be taught to boys with a chemical knowledge and only a limited general education. It is not so easy to teach them the chemical reactions involved, and the cause of the chemical changes they see. They can learn to use indicators by rote but do not know why the color changes. Consequently the least deviation from normal plunges them into difficulties.

The functions of the control laboratory are eight-fold:

1. Inspection of raw material. It is impossible to manufacture a first-class product if the raw materials are faulty or unsuited for the purpose intended. It is a duty of the control laboratory to determine the proper grade of material for every purpose used—which is not always the most expensive—and then by drawing up specifications hold all future shipments to the standard set. Many books have been written on the importance of correct sampling so it will only be mentioned here.

Whenever possible, raw materials must be tested before they are unloaded. This is especially true of materials received in tank cars which are unloaded directly into company tanks and thereby mixed with material from previous shipments. The control laboratory must be so organized that it can handle wide fluctuations in the receipt of raw materials.

2. Control tests on materials. The finished product of one department is often the raw material of another. Modern cost accounting requires inspection of a material which one department receives from another as much as one which it receives from another factory.

3. Testing of finished product. Everything we make is the raw material of our customers. Just as we test our raw materials so do our customers test theirs, according to their own specifications, and it is the duty of the control laboratory to see that nothing is shipped which does not meet specifications. Any rejection of materials causes a loss in time, in material, in goodwill, and the possible loss of a customer.

4. Laboratory control of plant processes. Whenever a special effort is made to improve a product or a method of manufacture, the whole procedure comes under the scrutiny of the laboratory. Samples for analysis are taken from every step in the process, every intermediate product, and every by-product. We can thus account for every pound of material entering into the process and find out where the losses occur. From the analysis of the intermediate products we can determine where the spoilage occurs. In this way a mass of experimental data is accumulated which usually points the way to improvement. The operating conditions are then varied, the changes caused by the variations noted, until the optimum conditions are determined. Then an operating manual can be drawn up, the chemist and chemical engineer go on to other problems and the process is left in the hands of the operators, under the supervision of a chemical engineer and the control laboratory.

5. Closely allied to the above is the procedure involved in the adaptation of a laboratory research to plant production. As soon as the new process has passed the beaker and test tube stage, a small experimental or pilot plant is set up in which it is possible to approximate actual operating conditions. The close control now exercised by the laboratory enables the chemical engineer in charge of the pilot plant

to vary the conditions of the process—temperature, pressure, time of action, etc.—until he finds the best method of operating. Here again comes in the time factor. Analytical results must be available promptly, so that as soon as one run is finished the data of that run can be tabulated and the conditions for the next run specified.

6. Analysis of new products made in the research laboratory. Very often the research chemist writes the equation of a reaction on paper and it looks good to him. He performs the experiment and gets a product. Sometimes he gets what he expects to and then again he does not. The control laboratory serves to keep his feet on the ground.

7. Analysis of competitors' materials. It is always a good idea to know what your competitor is doing. At the same time he is interested in keeping you from knowing. So he puts his new products in such a form that analysis is rendered as difficult as possible. He may mix a small amount of a similar substance to change the melting point beyond recognition, or add substances to make solubility determinations difficult, etc. Such phases of the work call for the exercise of intuition, psychology, and a general knowledge of the field, as much as chemistry. If you have a hunch as to what he is using it may be possible to devise tests to prove or to disprove the presence of that substance. This is often important in working up cases involving alleged patent infringements.

8. Interpretation of results. Simple tabulation of the results of an analysis is not always enough. Often results must be interpreted in terms that the non-chemical plant manager can understand. Results must be compared with previous results, variations explained, or they must be compared with other analyses of similar products, etc.

I have tried to show that there is more to analytical procedure than the routine performance of certain chemical tests. Observance of the principles of analytical technique will bring rich dividends in the form of improved products, conservation of materials and greater profits.

## CHEMISTRY AS AN AID IN MEDICAL DIAGNOSIS

By JAMES S. KLUMPP,  
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The beginnings in the modern field of research in physiological chemistry may be said to date from Liebig, the father of modern chemistry, whose contributions both as to analytical and organic chemistry paved the way for the establishment of the first two independent laboratories. Prior to 1880 medical chemistry, as it was called, was descriptive and not dynamic, with little of value to contribute to medicine. In 1883, Dr. Victor C. Vaughan, one of my old professors, was appointed to the chair of physiological chemistry in the University of Michigan. He was the first man to hold such an appointment in this country.

In the science of biochemistry, we have had a constant succession of new methods, and a very important phase of the research today has been the development of analytic technique. In the last few years there have been very great changes in the methods used for the analysis of urine, while the advancement in the field of blood analysis has been even more remarkable. The foremost characteristic of the successful modern analytical method is speed. With reference to the value of time, the biochemical investigator of today is no less keen than are the leaders in industry. Many of the older methods in use, say fifteen years ago—as, for example, Salkowski's method for uric acid, the method of urea, or the Schlossing method for ammonia—were accurate enough but they were slow and did not encourage the application of chemical methods in the study of clinical problems. When a physician had to wait four days to learn the amount of ammonia in a given specimen of urine, he did not bother himself very often with the determination of ammonia. Today an analytic method in urinalysis which cannot be finished in less than two hours is in need of further revision. Almost every material reduction in time and labor required for a given determination is followed by an increase in the number of investigators who make researches based upon that determination. But it is only when we come to the very shortest of biochemical methods that they appeal to the clinicians, and it is no small triumph for the modern technique that clinicians have begun to compete with laboratory specialists in the fields of research suggested by these new methods. A second characteristic of modern technique is the tendency to make the methods microchemical, and this is particularly important in blood analysis. For the older methods one to two hundred cubic centimeters of blood were required for satisfactory results; now we can run all the analyses with five cubic centimeters or less.

The most extraordinary knowledge has come to us from the sciences of physico- and physiochemistry. The dividing line between chemistry and physics has disappeared, and in many ways the science

of medicine has become merged with these two basic sciences in the past half century. Every phase of our existence is based on a physico-chemical reaction and this fact applies to the pathologic individual as well as the normal person.

In medical diagnosis we depend on three things, namely: 1. case history, 2. clinical findings, and 3. laboratory findings. It has not been many years since the practitioner of medicine had to depend entirely on the history and physical examination for his diagnosis, but in later years, by the aid of the chemist and physicist, we have bred the old timer's horse sense to cold scientific calculation and the off-spring is developing into modern medical diagnosis. A discussion of many particulars in which chemistry has been of aid in diagnosis would occupy too much time, so I shall merely enumerate several of the commonest and most outstanding features.

1. X-ray. The ray which is produced by the passage of an electric current of high frequency and voltage and low amperage through a vacuum or gas-filled tube would be of little advantage to the diagnostician unless the chemist and physicist had developed the uranium screen for fluoroscopic work. The X-ray photograph which is a permanent record of our findings in the part examined, is the result of a photochemical action fixed and developed by chemical reactions. The X-ray is used in conjunction with other products of the chemical laboratory for specific tests which will be discussed later.

2. Blood chemistry. Today, restoration of the sick can be as precisely accomplished in the living body as similar exchanges can be brought about in the test tube. The estimation of reclaimed excretory substances is now accurately made from hematologic studies, where formerly they were inaccurately estimated from the excretions, as, for instance, the urine. For example, in a probable case of diabetes mellitus, we are interested in the detection of glucose in the urine, but that finding in itself is of no definite value. The sugar thus found has been excreted and is past harming the individual. We must know exactly how much over the normal amount, that patient is carrying in his blood stream. This procedure and the following check-ups during treatment are made possible through chemical studies. In a case of nephritis we have definite chemical and physical means of determining the quality of urea per unit of blood. We look upon the kidney as a filter of molecular substances. Urea is one of the smallest of molecules and does not hydrate. The chemist has compounded the dye phenolsulphenophthalein, apparently of the same filterability as urea, and has made possible a ready test of urea filtration through the kidney. Two other chemical methods of blood examination which might be mentioned are the tests for bile pigments and chlorides.

In the analysis of urine a large number of chemical tests are commonly made. The tests for albumin and glucose have been in use for

many years and were the only laboratory tests the older practitioner had at his disposal. Other chemical tests now used are those for normal bile pigments, abnormal bile pigments, bile acids, indican, occult blood, acetone, diacetic acid, iodides, and other drugs.

In the writer's work there are two methods of diagnosis which have been of great value, and in which we are indebted to the chemist for his aid in their development. I refer to the visualization of the gall-bladder after the ingestion or intravenous injection of tetraiodo-phthalein, and the studies made in the spinal cord, sinuses and pelvic structures after the injection of lipiodol. In 1922 Forestier and Sicard first reported the use of lipiodol in their studies as to the cause of sterility in the female. Lipiodol is a combination of iodine and poppyseed oil; it is not a solution, but a definite chemical combination. Radiographically, it has a high degree of opacity, and is well tolerated by the body tissue. Forestier made over 5,000 injections without untoward results. It was first used in studying spinal cord tumors, later it was injected intratracheally in the study of bronchiectasis. In 1925 it was used in making an early diagnosis of pregnancy. This method depends on the fact that the pregnant uterus will not admit the entrance of the oil, and a negative X-ray picture is obtained, whereas the empty uterus will produce a well-filled shadow. I might add that in using this method of diagnosing a pregnancy, there is no danger of producing abortion. In the past three years many observers have demonstrated the possibilities of the use of lipiodol injections and X-ray in outlining the contour of the lumen of the tubes, and in locating obstruction in cases of sterility. The patient receives an anema and vaginal douche as a preparatory procedure. By the use of a speculum, the cervix is grasped by a tenaculum forcep and approximately eight cubic centimeters of 10 to 40% lipiodol are slowly injected into the cervix with a modified Keyes-Ultzmann syringe and cannula. The first X-ray exposure is made immediately. The nozzle is withdrawn and the patient is raised to a sitting position so as to drain the oil from the uterus. Some of the oil has passed into the tubes unless they are totally occluded, and this is brought out by a second exposure taken five minutes after the first. Thus an accurate picture of the uterus and tubes is obtained. When there is an occlusion, one is able to determine its exact location, which is of great value in cases of sterility, as one may be enabled to decide on the advisability of operative treatment. This technique may also be of value in the diagnosis of pelvic tumors especially if they impinge upon the uterus enough to produce a filling defect.

As mentioned before, one of the halogens is used in getting an accurate picture of the gall bladder. The first work was done by using an intravenous injection of tetra-iodo-phthalein. Later the substance was put out in capsules which were taken orally the night before the X-ray was made. For the last few months the substance has been on the

market in a palatable liquid form. By this method we are enabled to visualize directly the presence of stones in the gall bladder, which because of their consistency would not be visible otherwise. The absorption of the dye also demonstrates the thickened wall found in gall bladder inflammation of any standing.

These methods I have briefly discussed are but a few of many diagnostic methods which have their foundation on a chemical fact or procedure. The rapid development in diagnostic technique made in the past generation is undoubtedly due in a large extent to the cooperation between the clinician and his brethren in the allied sciences, especially the chemists, and physicists.

## SOLUBILITY OF HYDROQUINONE IN VARIOUS LIQUIDS

By W. H. WALKER,

This work is being carried out in partial fulfillment of the requirements for the degree of M. A. at West Virginia University under the direction of Professors Collett and Lazzell.

There are no fixed rules by which to predict whether a substance will dissolve in a given liquid or not, or to what extent. The probability that a solution can be formed increases with the resemblance of the solvent to the dissolved substance.

The Osmotic Pressure law of Van't Hoff, Raoult's law and Henry's law of Vapor Pressure have been the basis upon which the greatest portion of our present knowledge of solutions has been built.

These laws however deal with ideal solutions, and do not hold true in many instances. An ideal solution is one whose volume is equal to the sum of the volumes of the substances forming it; there is no heat evolved upon mixing the constituents; and the constituents of an ideal solution are able to dissolve in one another in all proportions. P-dibrom-benzol in benzol has been considered an example of an ideal solution.

From the Clausius-Clapeyron equation,

$$\frac{dp}{dT} = \frac{\Delta H_p}{RT^2}$$

it is possible to integrate and derive a form as follows:

$$\text{Log } N = \frac{\Delta H}{4.5757} \left( \frac{1}{T_m} - \frac{1}{T} \right)$$

Knowing the value of  $\Delta H$  (latent heat of fusion) it is possible to calculate the solubility at any temperature from this equation. When  $\log N$  is plotted against  $1/T$ , a straight line is obtained for an ideal solution.

In most cases  $\text{Log } N$  vs.  $1/T$  is not a straight line. Since this is true, then we have no basis for the exact predication of solubilities.

It was thought that if there was any relation among solubilities that it would be found among such compounds as  $C_6H_4xy$ , ortho, meta and para.

In a previous paper, (Collett and Johnson, *J. Phys. Chem.* **30**, 70 (1926)), were presented series of measurements of the solubility of the three introanilines in water, alcohol, benzene, chloroform, carbon tetrachloride, ether, ethyl acetate and acetone.

In another paper, (Lazzell and Johnson, *J. Phys. Chem.* (1928)), were presented a series of measurements of the solubility of the three aminobenzoic acids in the same solvents.

This work will be valuable in determining which solvent should be used in separating the isomers.

The results given in this paper on the solubility of *p*-dihydroxybenzene in various solvents, are those obtained in a study of the relative solubility of ortho, meta and para dihydroxybenzenes, in acetone, alcohol, benzene, carbon tetrachloride, chloroform, ether and water.

The hydroquinone used was J. T. Bakers C. P. and was purified as follows: It was first crystallized from 95% ethyl alcohol and recrystallized from water. This operation was repeated. Owing to the rapid oxidation of the crystals in the air, immediately after filtering, they were put into a desiccator, and dried in an atmosphere of hydrogen. The crystals were glossy white in appearance, small and needle-shaped.

The melting point as determined by the capillary tube method was  $173.0^{\circ}$ ; that given in the literature is  $169.0^{\circ}$ . All readings were corrected for emergent stems and were taken with a Bureau of Standards thermometer.

The solvents were very carefully purified.

The method of determining solubility is as follows: Glass tubing 5 or 6mm in diameter was cut into pieces of about 15cm length, washed in chromic acid solution, rinsed several times with distilled water and placed in a desiccator to dry. When dry, bulbs of 2-4cc capacity were blown at one end by melting one end of the tube in a very hot flame and gently blowing into the tube while rotating it. When cool these bulbs were annealed by warming gently in an ordinary gas flame. When cool they were cleaned and kept in a desiccator until needed.

One of the bulbs described above was weighed, a quantity of solute placed in the bulb and the whole reweighed, giving the weight of the solute. The stem of the bulb was then drawn into a capillary and a calculated volume of solvent introduced into the bulb. The bulb was sealed off at the capillary part of the stem. When cool, the bulb and contents was reweighed, giving the weight of the solvent used.

This bulb attached to the arm of an automatic shaker, made from a large electric doorbell, is immersed in a water or paraffine bath, the temperature of which can be carefully regulated. By slowly raising the temperature of the bath, vibrating the shaker the while, the temperature at which the last tiny crystal of solution dissolves, can be ascertained by a thermometer submerged in the bath near the bulb. The bath is slightly agitated with air bubbles, to keep the temperature uniform throughout.

Because hydroquinone is easily oxidized, it was deemed advisable to expell all air from the bulbs before sealing, by passing a current of dry hydrogen into the bulb and sealing immediately.

When determining the solubility of hydroquinone in chloroform, the solute turned black and curdled in large lumps. Furthermore, when running a check on the temperature, at which a certain bulb (mol

fraction) would dissolve; the solute dissolved at a slightly lower temperature than before. Upon running a second check on the same bulb, the solute dissolved at a still lower temperature.

This would tend to confirm the suspicion, that decomposition of the solute was taking place in the bulb. Further work on the solubility of hydroquinone in chloroform was suspended, when a bulb blew up with considerable violence.

Some difficulty was experienced in sealing the bulbs containing ether as a solvent, and some of those prepared proved faulty, the ether leaking out in the bath; so that the results to date are incomplete.

TABLE I.

Final Experimental Values of the Solubility, in Terms of Molal Percentage, of Hydroquinone in:

Acetone		Carbon tetrachloride	
C.	t.	C.	t.
100.00	173.0	100.00	173.0
82.84	160.2	86.73	167.2
71.55	148.5	71.20	163.2 (2LL)
58.78	131.5	57.01	162.9 "
46.45	105.3	46.11	162.9 "
40.61	90.2	5.36	163.8 "
35.17	69.5	1.89	154.0
21.25	45.5	1.42	147.4
		0.85	137.2
		0.69	132.6
Alcohol		Ether	
C.	t.	C.	t.
100.00	173.0	100.00	173.0
93.85	167.7	57.78	145.0
67.61	146.2	46.06	133.2
57.05	134.2	35.24	117.3
34.71	91.1	21.62	89.9
22.18	42.8		
Benzene		Water	
C.	t.	C.	t.
100.00	173.0	100.00	173.0
81.68	163.7	65.18	147.3
75.06	161.3	62.24	141.6
68.03	158.6	52.95	135.9
53.15	156.2 (2LL)	49.11	131.8
43.13	156.7 "	39.24	120.3
35.58	157.6 "	35.29	114.7
22.32	157.5 "	13.55	81.9
13.21	154.4	10.25	75.3
10.01	152.7		

Chloroform C.	t.
100.00	173.0
34.93	157.3 (2LL)
22.83	156.0 "
10.87	154.9 "
5.55	145.5
1.75	121.6

5.26 53.6

C equals 100(N) or Mol %.

All values of t. are the mean of from 2 to 4 determinations.

All temperatures marked (2LL) indicates that at that temperature and mol% there are two liquid layers and not a true solution.

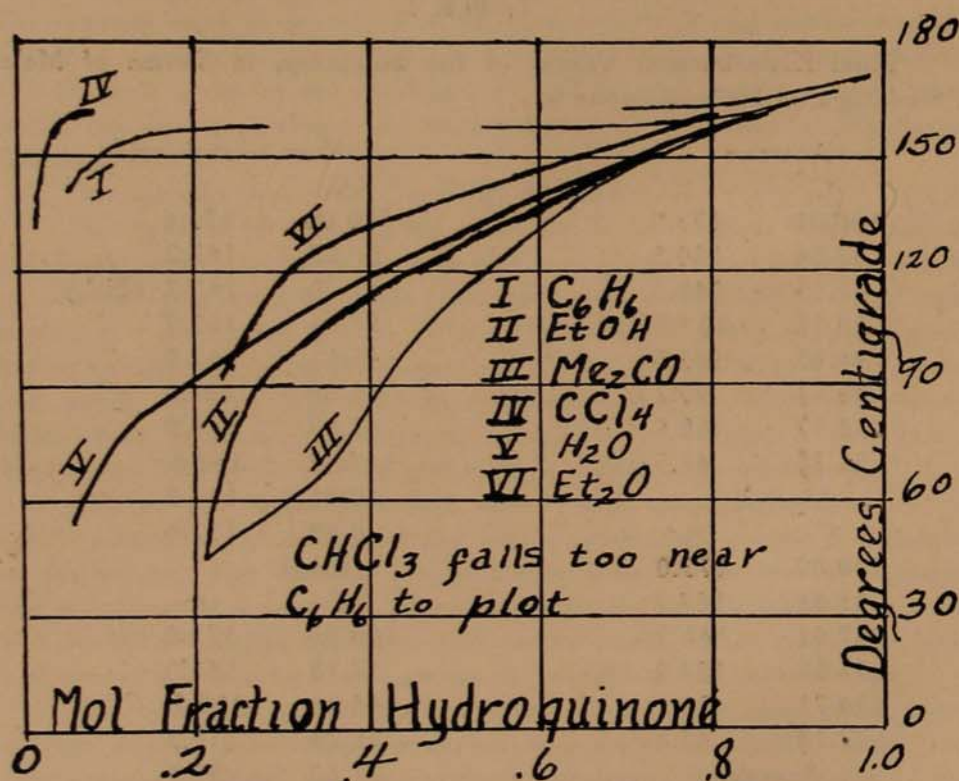


Fig. 1.

(All temperatures recorded in Table I are subject to revision, if errors are found in the thermometers used in the experiments, when they are calibrated again).

The following form of the Clausius-Clapeyron equation,

$$\text{Log } N = \frac{\Delta H}{4.5757} \left( \frac{1}{T_m} - \frac{1}{T} \right).$$

was used in calculating the points that determined the ideal curve for

the solubility of hydroquinone, as given in the International Critical Tables and J. A. C. S. 48, 1286, (1926), is 6480 calories per mol. This was the value used in determining the log mol fraction of solute at various temperatures. From these calculated concentrations and corresponding temperatures the ideal curve was plotted.

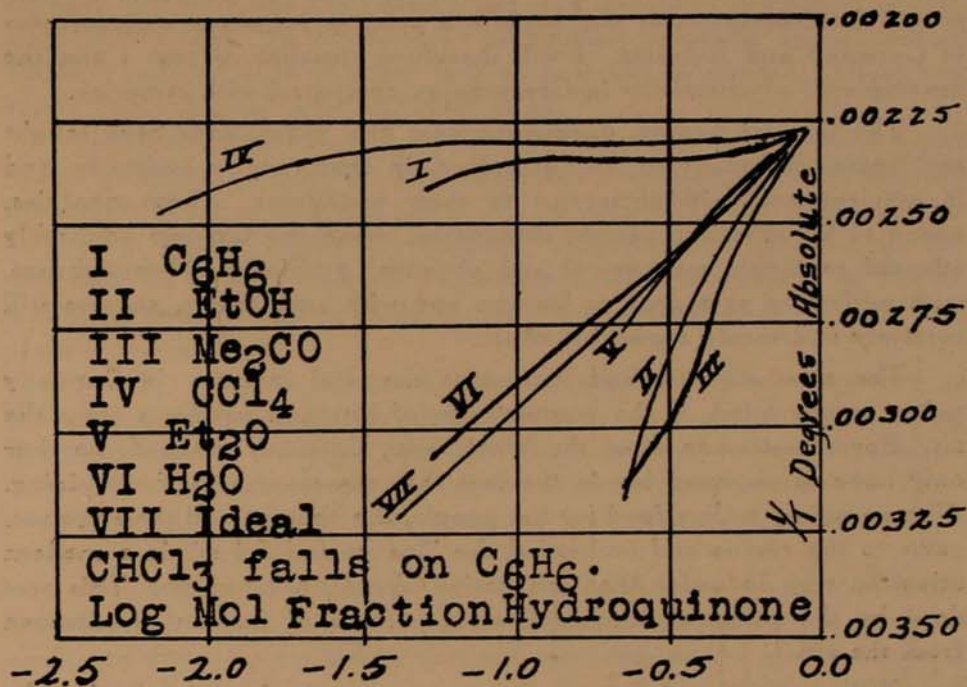


Fig. 2.

## A COMPARISON OF GERMAN AND AMERICAN INDUSTRIAL PROCESSES

By F. J. KAUFFMAN, Charleston, W. Va.

The subject which has been assigned to me is so broad that it can only be covered in a general way. My limited time will hardly permit the description of one important process; let alone the processes of Germany and America. I will therefore visualize as best I can the development of chemistry in Germany as compared with America.

The German people, during the past fifty years, have been taught and trained in loyalty to the Fatherland, in obedience to authority, and in efficient and faithful service to their employers. These qualities, added to his inherited patient disposition, make the German admirably adapted to tackle mechanical and chemical problems. Thoroughness, with perfection as a goal, is his aim and with such ideals, success will certainly and surely crown his effort.

The most gigantic and important chemical industry in Germany today, to my mind, is the manufacture of nitrogen products from the air. Poverty stricken after the World war, Germany realized that her only hope of recovery lay in the fact that she must be self sustaining. With no money to buy food for her people, the chemist and the engineer, came to the rescue and multiplied the "loaves and fishes" in a modern scientific way in order that the nation should not hunger. This was done by the chemical and mechanical process of fixation of nitrogen from the air.

With coal, air, and water for raw material, the scientist fed the nation by supplying plant food or fertilizer, thus increasing the productivity of the soil. Every farmer is taught how and what to use to increase the yield and even the children can converse intelligently on the choice of nitrogen, potash, or phosphorous in relation to its use as plant food for various kinds of crops.

These products of the air have other important uses. Nitrates can be produced for less cost than the natural mined product from Chili. Nitric acid can be made directly or combined with any desired base as nitrates. This important chemical has an extensive use in the nitration of coal tar products for manufacturing of dye intermediates, nitroglycerine, smokeless powder, and other high explosives.

Incidentally, there is made as raw material, a product commonly known as water gas which is made from steam and coal. Modern chemistry has taken this product and by the use of suitable catalysts has been able to produce methanol, commonly known as wood alcohol. It is entirely possible that this will at some future time be the principle constituent of motor fuel when necessity demands.

The water gas is separated into its two components, carbon mon-

oxide and hydrogen. The hydrogen can also be used to inflate the gas bags of Zeppelin aircraft. The carbon monoxide is used in large gas engines for the generation of electricity.

Two large plants are concerned in the manufacture of synthetic nitrogen products; one at Oppan, a little north of Ludwigshaven, and the other at Leuna. That at Oppan produces 110,000 tons of fixed nitrogen per year and the Leuna plant, the largest in the world, produces 550,000 tons. In the form of ammonium sulphate, approximately 100,000 railroad cars of thirty tons each would be needed. These two plants cover a total area of 2,000 acres.

These two plants employ about 40,000 men, of which about 1,200 of this number are chemists, engineers, and technicians. Every sanitary precaution is taken to guard the health of employees and their families. In case of illness, emergency stations, hospitals, and sanatoriums are provided, all free of charge. Protection against the effects of illness, disability, and old age is made through the establishment of relief and pension funds.

Another very important feature in the success of chemistry in Germany is the provision for making a thorough research investigation. Every facility for making a thorough study of any problem is supplied. The subject of study is analyzed by specialists in their profession. Plans for attacking the problem are outlined and then each investigator is assigned his particular piece of work.

About three months later another session is held and the results are reported. From the information at hand, the problem is analyzed again and the plan of attack is outlined according to the results reported. I was told that in one particular instance, ten men worked on the same problem for ten years before success was attained. This, you can see, is equivalent to the work of one man for 100 years.

Since the World war, the chemical industry in America has made wonderful progress. This was largely due to the fact that we were compelled to go into the business as a matter of necessity. The cost of chemicals increased to such an extent that almost any process could be used, regardless of how inefficient, and yet show a handsome profit. This condition was gradually changed with competition, and inefficient and wasteful processes have been abandoned and many chemical plants went out of business.

We have now approached the time when the chemical business in this country must stand on its own merits, as any other business. Just as the automobile and airplane has replaced the horse and carriage mode of travel, so will the new methods and processes in the chemical industry supplant those of today.

The industries which will survive will be those that succeed in developing new and more economical processes. This can be done only by maintaining a well equipped research department to work on

the problems at hand. Some of the most prosperous chemical industries were farsighted enough to follow this plan and are now reaping the profits of their investment. Others are still going on in the same way, refusing to spend a dollar unless guaranteed two in return.

In this field of endeavor, I believe that German industries surpass our own. They also have the advantage of cheap labor which enables her to work up by-products and show a profit whereas in this country, it would result in a loss. Efficiency and economy is her motto.

We, however, have an advantage in having a wealth of natural resources. These, as yet, can hardly be said to be touched.

I believe that our chemists are just as capable and if a more sincere effort is made by the industries in this country to improve their processes, and find new ones, there is no doubt that we can overcome the cheap labor advantage which the European countries now enjoy.

## THE VITALIZATION OF HIGH SCHOOL CHEMISTRY

By W. H. CORNETET,

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It is possible to think of many desirable objectives for teaching students in high school, chemistry. There are many good reasons for including chemistry in the high school curriculum. Yet the teacher of this subject is confronted with certain tasks, for which he must plan carefully, if he is to make his course a valuable one to his students.

The most important of these tasks are (1) to find a means of creating an interest and appreciation for the subject, within the student; (2) to have the student acquire a knowledge of the fundamentals of chemistry, so that he will have a foundation upon which he may build, later. These fundamentals will be the same, whether or not the student intends to enter a standard college, or the great "university of experience." (3) To encourage the student to develop a scientific method of thinking, and to apply this in the common affairs of his everyday life. (4) to instill in the mind of the student the possibilities of unselfish service to mankind, in the field of chemistry. We can sum up all these tasks by saying that the chemistry teacher must find methods, by means of which he can make his subject "vital" important to his students.

The teacher in high school chemistry occupies a unique position. It is unique, both in its opportunities and in its responsibilities. When a student, for the first time, enters a chemistry class, he is at the threshold of a new endeavor. The responsibility that rests upon the teacher is that of creating within the student an interest for something that is entirely new. First contacts and impressions are usually the ones that last. It is, therefore, highly important that the teacher grasp the opportunity of making the first impressions in the minds of the students, favorable. This must be done in the first few class meetings.

A superficial "first" interest might be created by performing a few striking experiments. This does not leave the desirable impression, for it gives the student the idea that chemistry is magic or super-natural. On the other hand, the students should be shown that chemists are dependent upon nature to furnish the raw materials with which they work, and that chemistry is very natural. To get the students to realize the "nearness" of chemistry and its importance to their own health, happiness and comforts of life, is not always an easy task.

Means of capturing the student's "first interest" are many. One that has proved very successful, is to skillfully guide them on a chemical visit through their own home. Show them that the many materials they enjoy or take for granted, are the results of chemical process. Materials, such as cement, mortar, plaster, wood, and so forth, of which their houses are composed, are of this type. Tell them that the beautiful

colors in the carpets, draperies, and even their own clothing, in all probability had their origin in a piece of coal; even the medicines in the medicine chest, the vanilla and the wintergreen flavors in the kitchen cabinet, and the perfumes and toilet waters may have had their origin in the same source. Show them how the chemist controls the use of natural gas, making it possible either to heat the home or to cool the refrigerator with it. The story can be continued to almost any length, for any direction you turn, new examples will loom in view.

Another method of capturing the "first interest" is to select the element, sulfur, and picture modern civilization without it. A mere mention of its importance to the automobile tire or storage battery, is usually enough to start the student to thinking in the right direction. Other elements or compounds could be used for this purpose, with the same result.

Before discussing specific methods of "vitalization," those parts of chemistry that might be considered fundamental, should be mentioned. To understand chemical processes, whether under discussion in the classroom, or found in the daily newspaper and current magazine, the student should master the following: (1) Know the significance of the terms, element, compound, mixture, acid, base, salt, atom and molecule. (2) Be able to use valence in the writing of simple formulas, and to name the simpler compounds. (3) Be able to write equations for reactions of synthesis, analysis, single and double replacement. (4) Be able to make calculations, based on the simpler reactions. To be sure, this list does not include all of the minimum requirements of a high school course in chemistry, but a student who has mastered these things, will be able to figure out the other chemical problems that are sure to arise.

There are several "laws of learning," but the one that fits our case best now, is "that we learn by doing." It is probably because of the laboratory, that the subject of chemistry is considered so much different from others. However, for the laboratory to accomplish its purpose, its use must be carefully planned. Close correlation between the laboratory and classroom is necessary. This can best be secured by having the laboratory manual incorporated within the text book, placing the experiments strategically. As a general rule, experiments should be performed before the subject under consideration is discussed in the classroom. By doing this the student will make use of his experimental results in interpreting the information contained in the text-book. Facts discovered by the student for himself, are the most impressive. Laboratory work can be made more beneficial if the laboratory is arranged and kept in a systematic order. Scientific thinking will be the result of systematic study.

After capturing the student's first interest, the teacher's problem is now to make this interest permanent. Properly conducted laboratory work goes a long way to solve this problem. Numerous demonstrations

are necessary at the beginning of the course in order to acquaint the students with the "laboratory method." No harm is done by having the student repeat some of the demonstrated exercises for himself. This repetition, on the other hand, gives the student the necessary confidence to attack new problems for himself. Continuing the idea that "learning is accomplished by doing," as the student advances, it is probable that only experiments involving poisonous or obnoxious gases, and those involving considerable apparatus or extremely accurate weighing, should be demonstrated.

The photographers association of America, in a recent national advertisement, emphasized that pictures make ideas permanent. Good pictures and diagrams have a great deal to do in making a chemistry course "real" to the student. The blackboard is a valuable visual aid, and is widely used. The projection lantern and the portable movie machine are destined to be most valuable as "vitalizing" agents, in teaching. The value of these machines is determined by the quality of the projection material, and the skill in its use. Suitable slide material for chemistry is difficult to obtain. Probably the most satisfactory way of obtaining this, is for the teacher to manufacture his own slides. This, of course, involves a good deal of equipment and money, in addition to many hours of concentrated effort. The author is now in the act of preparing a set of slides, suitable to accompany the high school chemistry course. This may in time be available to other teachers of chemistry, if they so desire.

Many manufacturing concerns now have films available, which picture chemical processes that are used in industry. The Eastman Kodak Co., has recently organized a \$1,000,000 corporation, known as the Eastman Teaching Films Co., Inc., whose purpose is to manufacture films for class room use. These films will include many dealing with chemistry. Recent tests, nation wide in scope, have proved that pupils taught by the use of such films, have increased their average 24%. Since most students fail by less than 24%, it is evident that many failures would be changed into promotions. The use of films and slides is not meant to take the place of older, standardized methods of teaching, but to be valuable supplements to them.

The use of a projection lantern must be so managed, that it will not misplace the attention of the students. Since it is probable that only one or two slides will be used during the recitation, the equipment must be so arranged that this material can be shown the instant it is needed in the discussion. To do this, the lantern should be in the front of the room, just a step from the lecture table. A translux screen is most desirable, but very good results are obtained by placing a silvered screen at one side of the room and the lantern at the other. With this arrangement, it is not necessary that the room be entirely darkened. This is desirable, for it permits the students to take notes on the slide

material, and also extends the use of slides, to charts and graphs.

The teaching of chemistry is placed on a truly scientific basis, when the electronic conception of matter is made the basis of the course, for many mysteries of the subject are explained by it, and it connects many otherwise disconnected phenomena. Some educators say that the structure of the atom should not be included in high school chemistry. The author has found it to be one of the most enticing subjects to his students. Many students have constructed original models of atoms and molecules. When the electronic idea is carried clear through the course, not added as an extra chapter, it is found to be a most valuable vitalizing factor.

The making of atomic models calls for a brief discussion of projects. The number and types of projects is unlimited. Many manufacturing concerns are glad to contribute material, which will permit students to work on projects of a permanent character, portraying chemical processes of manufacture. Projects should not be undertaken by students, at the expense of the rest of their chemistry course. Projects, properly organized and carried out, are valuable means of creating and maintaining interest.

Probably one of the most difficult subjects in chemistry to teach, and yet one of the most important, is valence. To be able to properly use valence is an asset to any student. Most of the student's trouble with valence, originates in a misunderstanding of its purpose. By carrying out properly arranged experiments, such as finding the formula of a compound by analysis, the student can be led to see the necessity of a scheme for writing formulae. Once he sees a need for valence, he willingly attacks the mastery of it. The student should be taught to deduce the valence of elements from known formulas, using standard elements for comparison, rather than memorize it. This can be done by using exercises containing formulas so arranged that the student will use standard elements to deduce the valence of new elements. Continuing in the exercise, he will derive new valences from those previously deduced. When he has become efficient in this, he will be capable in using valence. Charts, arranged so that positive and negative radicals can be joined to make formulas, develop skill and ability, in the use of valence.

The student should be shown applications of scientific principles, as he proceeds in the course. He should be encouraged to apply his scientific knowledge in the affairs of his daily life. Often times, students get the idea that purely scientific principles and laws are of no practical value. It is probably well at these times to mention some applications. One as striking as any, is that of Dalton's law of gases, formulated by John Dalton in 1802. In this he stated that "in a mixture of gases, each gas exerts the same pressure as if it alone occupied the entire vessel,

and the total pressure is the sum of the partial pressures of the different gases".

This law continued to seem only of scientific interest for over a hundred years. When a practical application was found, it was found in the "gas refrigerator," a common household necessity. The gas refrigerator would have been in use twenty years sooner, had the original inventors made use of the law. Two Swedish students in working for a higher degree, selected the gas refrigerator as their problem. They found that by applying Dalton's law, putting hydrogen and ammonia gas in the refrigerating chamber, that the refrigerator could be made to work. This is what the original workers on this problem had failed to do. Examples of this type, soon dispel doubt as to the value of purely scientific facts.

For a teacher to make his course "vital" to his students, he must himself, be filled with enthusiasm for the subject. He must be overflowing with it. Yet one of the most valuable things he can do for his students, is to show them the unlimited opportunity for unselfish service to mankind, in this field. References to men like Pasteur, who, with his labors in the field of chemistry, has saved more lives than any other one person; or Firestone, who labored to find a way to vulcanize rubber, thus making this wonderful substance useful to man in many ways; or William Henry Perkin, who as a hard working boy, opened the great field of coal tar dyes, should serve as fitting examples of these opportunities. The words "unselfish service" are used, because the real scientist does not think of self. He is usually a keen minded person who labors with a new idea, striving to find all the facts he can, concerning it. He is not after, nor does he gain publicity. If he should die before his goal is reached, he passes on his information to other scientists, that they may finish his task, thus benefiting humanity as a whole. No course in chemistry is complete without Slosson's "Creative Chemistry." This book has done and can do, more to create interest in chemistry and to show its possibilities, than any other one agency.

In striving, then, to make the high school course in chemistry vital to the student, we must first create an interest in the subject by showing a need for it. Once the need is found, the interest of the student becomes permanent. Mastery of the subject is obtained by presenting it in an understandable form. Chemistry is made understandable to the student by discussing it in accordance with the "scientific method," that is, to develop the subject matter as it should unfold in the student's mind. With a mastery of the subject, the student will be desirous of applying his knowledge. This accomplished, the subject has been made "vital" to the student.

## THE MONONGAHELA SERIES IN EASTERN OHIO

By WILBUR STOUT,

State Geologist of Ohio, Columbus, Ohio.

## Introduction.

The Monongahela Series in eastern Ohio appears at the surface in an area of 1,213 square miles and extends under Permian covering in 1,830 square miles, thus making in all an extent of surface of 3,043 square miles. Such strata are present in a belt bordering the Ohio River and extending from northern Jefferson to southern Lawrence County. The length in a direct line is close to 180 miles and the width varies from one to 45 miles. Areas of 100 square miles or more are found in Jefferson, Belmont, Monroe, Noble, Morgan, Athens, Washington, and Meigs counties and those of lesser extent in Harrison, Guernsey, Muskingum, Lawrence, and Gallia counties.

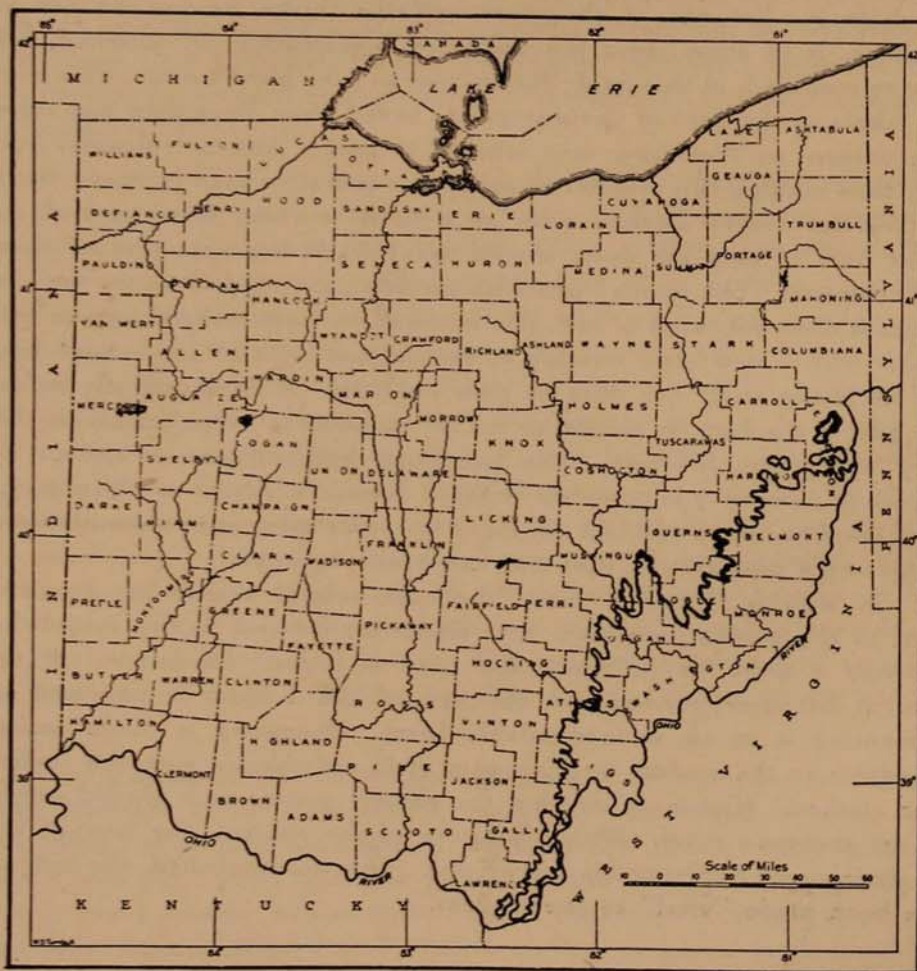


Fig. 1.—Western margin of the Monongahela Series in Ohio.

### Rocks of the Monongahela Series.

The strata consist of limestones, shales, sandstones, and coals. Conglomerates in the true sense are absent and iron ores are present only as nodules in the shales. The limestones are all of fresh-water origin as is indicated by the small fauna of gastropods, ostracods, and other diminutive forms of shell life. These rocks vary in color from light to dark gray, in texture from soft chalky to dense smooth, and in composition from very shaly to quite pure. The beds show the irregularity in thickness and the lenticularity in form usually attendant with fresh-water deposits of calcareous matter. These limestones are always interbedded with shale and frequently give way laterally to such material. The members now named are, in ascending order, Redstone, Fishpot, Benwood, Uniontown, and Waynesburg.

The shales in the Monongahela Series vary widely in both physical and chemical properties. Some of them are of the ordinary gray, siliceous variety tending towards the shaly sandstone phase. Others are decidedly calcareous in composition. These vary from soft sticky red shales, through drab grainy to light gray marly materials. The ferruginous shales may be divided into two kinds, one, a soft red plastic shale retaining the original characteristics of the sediments and another, much the same physically, but derived from the weathering of calcareous shale. The latter is only red in the zone of weathering but the former has that color under deep coverings. Soft smutty carbonaceous and hard bone shales frequently accompany the coal beds. The only shales in this group of rocks that so far have received names are the Fulton Green and the Annabelle members.

The sandstones in this division of rocks have the common range of properties for such materials in the coal formations, that is, they vary from fine to coarse, from friable to well bonded, from very impure to moderately pure, from light gray through buff and brown to pink, and from thin bedded to massive. Most of the larger deposits of sandstones appear to be of delta origin but some are evidently of shore deposition. The beds are erratic in thickness and are lacking in continuity. The members now named are, in order of deposition, Upper Pittsburgh, Lower Sewickley, Upper Sewickley, Arnoldsburg, Uniontown, and Gilboy.

The coal beds found here are not unusual in any way. In general, however, they are more impure than those in the lower part of the Pennsylvanian System. To what factors this effect of decrease in ash in the older coals is attributed is not evident unless it is to less infiltration of sediments through more effective marginal barriers or to less periodic floodings with supplies of silts from the uplands. During the time of deposition of the older coals the supply of silts was less, the loss by solution was greater, and the conditions of deposition were more uniform than they were during that of the younger ones. There is also a difference in the place of formation. The Pottsville and Allegheny

coals, for the most part, were laid down along the borders of marine waters whereas the Monongahela beds were deposited along the shores of fresh water swamps and lakes. This is shown by the fact that all the coal members in the Pottsville Series and most of those in the Allegheny are directly overlain by limestones and shales with marine or brackish water fossils. A slight subsidence caused the sea to flood the coal forming areas. With the Monongahela members the conditions are different. Nearly all the coal beds in this series of rocks are underlain by fresh-water limestones and some of them are also overlain by similar material. Periodic flooding of these swamps was effective in bringing in considerable silt which forms the closely spaced papery partings of shale that so largely increases the ash content. The associated bone shales appear to have been deposited in the more open waters and to have been formed from normal silts with the addition of macerated carbonaceous matter from water-loving plants. Further, the bone shales are the common carriers of the remains of the animal life. Aside from the Pittsburgh in the main Belmont, Ohio, field the coal beds in the Monongahela Series show much irregularity in thickness and in structure due to the shifting of conditions in the areas of deposition. Beyond the fields of thick coal the several horizons are nearly always marked by thin shaly coal, or by bone shale, or by a mere soot streak of "mother" coal. The largest wants, not often more than a few miles across, are through replacement by sandstones. The coal beds recognised in the Monongahela Series of Ohio are the Pittsburgh, Redstone, Fishpot, Sewickley, Uniontown, Little Waynesburg, and Waynesburg.

#### Thickness of the Monongahela Series.

The thickness of the Series is rather uniform across the state. The maximum variation is from 220 to 270 feet. The average measurement of the Series and of the various intervals in the different counties are given below:\*

COUNTY	From base of Pittsburgh to base of Redstone coal.		From base of Redstone to base of Fishpot coal.		From base of Fishpot to base of Sewickley coal.		From base of Sewickley to base of Uniontown coal.		From base of Uniontown to base of Little Waynesburg coal.		From base of Little Waynesburg to top of Waynesburg coal.		Thickness of Monongahela Series from base of Pittsburgh to top of Waynesburg coal.	
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
Belmont	31	5	35	2	24	4	112	5	29	10	19	10	253	0
Monroe	23	0	29	6	27	7	113	4	34	8	24	2	252	3
Noble	26	4	36	3	27	4	120	0	38	6	14	3	262	8
Washington	24	0	23	4	20	0	116	2	42	11	15	9	242	2
Morgan	23	9	33	3	15	0	101	11	45	4	15	3	234	6
Athens	23	6	40	1	24	3	106	4	37	5	12	0	243	7
Meigs	27	3	36	4	23	0	101	0	47	6	10	8	245	9
Average	25	7	33	5	23	1	110	2	39	5	16	0	247	8

\*These intervals may be changed slightly in some of the counties as all the field work is not yet completed.

## General Sections.

A general section of the rocks of the Monongahela Series in Belmont County is approximately as follows:

	Ft.	In.
Coal, <b>Waynesburg</b> .....	3	2
Shales, siliceous with shaly sandstones .....	16	4
Coal, <b>Little Waynesburg</b> .....	..	4
Limestones, with calcareous shales, <b>Waynesburg</b> ..	10	0
Shales with local lenses of <b>Uniontown</b> sandstone ..	18	4
Coal, <b>Uniontown</b> .....	1	6
Shale and sandstone .....	9	0
Limestones, with calcareous shales, <b>Uniontown</b> ..	41	0
Shale, siliceous, calcareous, greenish, <b>Fulton</b> .....	3	2
Limestones, with calcareous shales, <b>Benwood</b> .....	52	7
Shale, calcareous .....	4	0
Coal, <b>Sewickley</b> .....	2	8
Shale, argillaceous .....	3	0
Sandstone, <b>Lower Sewickley</b> .....	16	10
Shale, gray, siliceous .....	3	0
Coal, <b>Fishpot</b> .....	1	6
Limestones, with calcareous shales, <b>Fishpot</b> .....	26	2
Shale, calcareous .....	8	0
Coal, <b>Redstone</b> .....	1	0
Limestones, with calcareous shale partings, <b>Redstone</b> .....	17	5
Shale, calcareous .....	6	0
Coal and partings, <b>Pittsburgh</b> .....	8	0
Total .....	253	0

The rock column in Morgan county is as given below:

	Ft.	In.
Coal and bone shale, <b>Waynesburg</b> .....	0	7
Shale, argillaceous, drab .....	1	0
Shale, gray, siliceous, with thin lenses of <b>Gilboy</b> sandstone .....	13	4
Coal and bone shale, <b>Little Waynesburg</b> .....	..	4
Shale, drab, calcareous, grainy .....	9	0
Shale, calcareous, pink, with occasional layers of limestone .....	12	0
Shale, gray, siliceous, with local lenses of <b>Uniontown</b> sandstone .....	23	7
Coal and bone shale, <b>Uniontown</b> .....	..	9
Shale, gray, siliceous, irregular, local .....	2	6
Limestone and calcareous shale, <b>Uniontown</b> .....	31	3

Sandstone and siliceous, gray shale, very local 1 to 15 feet in thickness, <b>Fulton horizon</b> . . .	3	0
Limestone and calcareous shale, <b>Benwood</b> . . . . .	63	0
Coal and partings, <b>Sewickley</b> . . . . .	2	2
Clay shale, gray to drab . . . . .	3	0
Shale and shaly sandstone . . . . .	11	10
Coal and bone shale, <b>Fishpot</b> . . . . .		2
Limestone, massive, with shale partings . . . . .	10	5
Shale, calcareous, with some limestone layers <b>Fishpot</b> . . . . .	19	3
Shale, gray siliceous . . . . .	3	3
Coal and bone shale, <b>Redstone</b> . . . . .		4
Shale, gray, siliceous, with local lenses of <b>Upper Pittsburgh sandstone</b> . . . . .	22	10
Coal and bone shale, <b>Pittsburgh</b> . . . . .		11
Total . . . . .	234	6

The Monongahela Series of rocks has approximately the following structure in Meigs county:

	Ft.	In.
Coal and carbonaceous shale, <b>Waynesburg</b> . . . . .		2
Shale, soft, argillaceous, light gray . . . . .	1	0
Shale and shaly sandstone, gray . . . . .	9	5
Coal and bone shale, <b>Little Waynesburg</b> . . . . .		1
Clay shale, drab, grainy . . . . .	10	6
Clay shale, red, calcareous . . . . .	12	0
Shale and shaly sandstone, gray . . . . .	24	10
Coal and bony shale, <b>Uniontown</b> . . . . .		2
Clay shale, red, calcareous, with occasional thin limestone layers . . . . .	41	0
Shale and shaly sandstone, gray. <b>Fulton horizon</b> . . . . .	18	0
Clay shale, red, calcareous, with some thin and marly limestone, <b>Benwood</b> . . . . .	21	9
Sandstone, massive to shaly . . . . .	20	0
Coal, <b>Sewickley</b> , often replaced by sandstone . . . . .		3
Sandstone, massive, with some shales locally . . . . .	22	10
Coal and bone shale, <b>Fishpot</b> , usually replaced by sandstone . . . . .		2
Sandstone, massive . . . . .	30	1
Shale, gray, siliceous . . . . .	3	5
Coal and partings, <b>Redstone-Pomeroy</b> . . . . .	2	10
Clay shale, calcareous . . . . .	3	6
Shale with sandstone lenses . . . . .	21	5
Coal and partings, <b>Pittsburgh</b> . . . . .	2	4
Total . . . . .	245	9

## Pittsburgh Coal.

The Pittsburgh coal is not only persistent but is very uniform in thickness and in structure in the Ohio field in Jefferson, Belmont, eastern Harrison, southeastern Guernsey, and eastern Monroe counties. The main or lower stratum of coal is regularly divided across the entire field into "Bottom," "Brick," "Bearing-in," and "Breast" coal by thin partings of bony shale. Above this is the thick parting of gray calcareous shale or draw slate superimposed upon which is the "Roof" coal ordinarily broken by several thin irregular partings of coaly shale and shaly coal. From nearly one hundred measurements well scattered across the field the mean thickness and structure of the Pittsburgh coal is approximately as given below:

	Ft.	In.
Coal, "Roof," shaly .....	1	4
Shale, calcareous, "Draw" slate .....	..	8
Coal, good, "Breast" .....	1	7 $\frac{5}{8}$
Shale, bony .....	..	$\frac{1}{2}$
Coal, good, "Bearing-in" .....	..	4 $\frac{1}{4}$
Shale, bony .....	..	$\frac{3}{8}$
Coal, good, "Brick" .....	1	5 $\frac{5}{8}$
Shale with pyrite, "Copper" band .....	..	$\frac{3}{8}$
Coal, good, "Bottom" .....	1	2 $\frac{1}{8}$
	<hr/>	
Total .....	6	8 $\frac{7}{8}$
Coal mineable in main stratum .....	4	7 $\frac{5}{8}$

On southwestward from the Belmont field the Pittsburgh coal is much impoverished in western Monroe, Noble, Morgan, Muskingum, and Washington counties. The change takes place in southeastern Guernsey and eastern Monroe counties. Along the outcrop, where the conditions are favorable for observation, the member decreases from nearly five feet of coal to a few inches of bony shale in a distance of one or two miles and locally even in that of one-fourth mile or less. Although the Pittsburgh member disappears as a real coal bed the horizon is nearly always marked by a thin stratum of bony shale, by coaly shale, or by local lenses of coal. The thickness of the deposits of carbonaceous shale is usually between one-eighth and six inches and that of the lenses of coal from one inch to one foot eight inches. Through such deposits the horizon of the Pittsburgh coal may be traced with ease.

In the north central part of Washington county in the vicinity of Lower Salem and Whipple a small body of coal of excellent quality and from two to three feet in thickness is present in an area of about 15 square miles. This coal is not Pittsburgh as it is commonly considered. It is bedded within the body of the Pittsburgh limestone. Its

position is thus from 10 to 15 feet below that of the true Pittsburgh coal which here is represented only by a thin layer of bony shale lying above the limestone.

In northeastern Athens county the Pittsburgh coal again appears with excellent thickness and with fair quality in what is known as the Federal Creek field which is about 12 miles in length but less than one-half of this in width. In a general way the structure of the Pittsburgh coal in the Federal Creek field is somewhat similar to what it is in the Belmont field. The deposits in both areas are regularly divided into two major divisions of coal by a thick parting of gray, calcareous shale. The comparison is approximately as follows:

	Federal Creek field		Belmont field	
	Ft.	In.	Ft.	In.
Coal with bone shale partings . . .	4	6	1	4
Shale, gray, calcareous . . . . .	1	0		8
Coal with thin partings . . . . .	3	8	4	9

In both fields the upper bench of coal is far less steady and uniform than the lower one. In the Federal Creek field it contains fuel of better quality than is found in the lower stratum which is the reverse of the conditions in the Belmont field. Along the borders of the productive field in Athens county the Pittsburgh member is subject to rapid changes in thickness. In places it decreases abruptly from a thick bed of coal to a thin layer of hard carbonaceous shale. In its extension southward into Meigs county the Pittsburgh member is very erratic in development but it is nearly always present in some form, ordinarily bearing both coal and carbonaceous shale. Where represented by the shale phase alone the thickness of the bed is never more than a few inches but where coal also appears on the horizon it varies from a few inches to over four feet. The conditions are not far different in Gallia County except in a small area known as Swan Creek field where the Pittsburgh coal maintains mineable thickness over parts of five townships. In eastern Lawrence County the member is more impoverished in character but is equally persistent in extent.

The geological examination thus shows that the Pittsburgh coal with few and then only local wants extends across the state from northern Jefferson to southern Lawrence county. The thickness of the bed, however, varies from one-eighth inch to 10 feet and the character of the material from hard bone shale to coal of high purity. This member is always attended by the Pittsburgh limestone which is remarkably persistent throughout the entire area. During this general swamp period limestones were first deposited to fill the basin to where more advanced types of plant life could gain a footing with the result that then the land plants gave vegetable tissue for the formation of coal

and those in the more open shallow waters provided carbonaceous matter for cementing the land derived silts into bone shales.

#### Upper Pittsburgh Sandstone.

The upper Pittsburgh sandstone is a member with no definite stratigraphic value in Ohio as it is entirely absent in wide areas and is never persistent over a broad field. The deposits are local and most common in southeastern Harrison, northwestern Belmont, north central Washington, southeastern Morgan, and central Athens counties. In these localities the member extends from 5 to 30 feet in thickness and becomes massive in character. In general in Jefferson, Belmont, Harrison, Monroe, and Guernsey counties the interval between the Pittsburgh and Redstone coals is made up of limestone and calcareous shales whereas in most of Noble, Morgan, Muskingum, Washington, Athens, Meigs, and Lawrence counties it is composed mainly of gray shales with only thin irregular lenses of shaly sandstone. Where present the Pittsburgh sandstone is gray to drab in color, medium fine in texture, and commonly marked by cross-bedding planes. The bond is ferruginous and argillaceous matter, and the prominent minerals, aside from quartz, are muscovite, chlorite, and limonite.

#### Redstone Limestone.

In most of the areas covered by Monongahela rocks in Belmont, Jefferson, Monroe, Harrison, and Guernsey counties the Redstone member, consisting of limestone and calcareous shale, occupy all or nearly all of the interval between the Pittsburgh and the Redstone coals. The deposits usually measure between 15 and 30 feet. Both limestone and shale, as indicated by the fossils which are few in number and small in size, are of fresh water origin. In texture and in composition these rocks are quite similar to those in the Fishpot, Benwood, Uniontown, and Waynesburg members, lying higher in the Monongahela Series. Through the central part of the field in Noble, Morgan, Muskingum, Washington, and Athens counties the Redstone limestone is almost entirely wanting, its place being taken by siliceous shale and shaly sandstone. In Meigs, Gallia, and Lawrence counties the member again appears in an impoverished way. The deposits are local and thin and consists of red clay shale with some marly lime. On the whole the Redstone limestone may be considered an eastern Ohio member as the general swamp condition of that period was confined to that area.

#### Redstone Coal.

The Redstone coal in the Monongahela Series of Ohio is a definite and persistent member in only two fields which are widely separated, one being in southern Ohio and the other in the eastern part of the state. The largest and most important of the two is that present in southern Ohio where the Redstone or Pomeroy coal has mineable

thickness in southern Meigs and eastern Gallia counties. The bed, however, is regularly present but much diminished in thickness in eastern Lawrence, northern Meigs, and southern Athens counties. In the Pomeroy field proper the Redstone member has a mean thickness of over four feet and lies from 25 to 35 feet above the Pittsburgh coal. In its extension northeastward from southern Athens to southern Belmont county the Redstone coal is very unsteady, in fact, it is absent far more often than present. Where observed the member is commonly represented by a thin layer of bony coal or by a mere streak of sooty carbonaceous matter. In eastern Belmont and in southern Jefferson counties the Redstone member again swells to as much as two feet in thickness by the addition of coal to the bone shale. In this field the bed lies directly above the Redstone limestone and just below the Fishpot limestone. It is thus bedded within the limestones indicating that swamp conditions prevailed throughout the whole time. In Ohio the Redstone coal, although quite irregular in areas, is sufficiently well marked to be followed with a degree of certainty from Jefferson County to Lawrence County.

#### Fishpot Limestone.

The Fishpot limestone, named by J. J. Stevenson in 1875, for deposits on Fishpot Creek in Washington County, Pennsylvania, is one of the most persistent members of any kind in the Monongahela Series of Ohio as it crosses the state with few wants and with little diminution in thickness. It becomes less calcareous or more shaly, however, in its extension southwestward but it always contains some marly and regularly bedded limestones along with the more silty materials. It is replaced by sandstone in most of Meigs County and in parts of Gallia and Lawrence. Further, it is locally divided about midway by thin lenses of sandstone or of sandy shale in Athens, Morgan, and Washington counties. Throughout the main field from Jefferson to Athens County the average thickness of the Fishpot limestone is not far from 31 feet whereas in the unsteady area in Meigs, Gallia, and Lawrence counties the usual measurement of the local deposits is between five and 25 feet. The Fishpot limestone is quite similar in origin, structure, texture, and composition to other limestones in the Monongahela Series.

#### Fishpot Coal.

The Fishpot coal, the third carbonaceous member in the Monongahela Series of Ohio, lies on the average, 59 feet above the base of the Pittsburgh coal and 23 feet below that of the Sewickley coal. The stratum is of little value as a source of fuel even in the areas of best development. The coal, however, is of some interest stratigraphically as it lies directly above the Fishpot limestone and as it is overlain by siliceous shales and shaly sandstones which appear to have closed the general swamp period that began with the Pittsburgh or even with the

older Summerfield limestone. The Fishpot coal is quite persistent in eastern Ohio in Jefferson, Harrison, Belmont, and Guernsey counties. In this part of the field it varies from a few inches to over four feet in thickness and from a simple to a composite structure in which good coal, shaly coal, coaly shale, and bone shale may all figure prominently. On to the southwestward in Noble, Washington, Morgan, and Athens counties the Fishpot member is commonly present on the horizon but the representative material is bone shale seldom more than a few inches in thickness. In Meigs, Gallia, and Lawrence counties this member is largely absent through replacement by sandstone. The Fishpot coal and its associated limestone are quite definite units throughout most of the Ohio field and therefore deserve recognition as distinct members in the Monongahela column.

#### Lower Sewickley Sandstone.

The Lower Sewickley sandstone is a unit of no great prominence in Ohio. It lies between the Fishpot coal and the Sewickley coal which interval is, on the average, about 23 feet in thickness. In a few places this member has massive development, occasionally even expanding enough to replace the underlying or the overlying coal with some associated strata. Although the Lower Sewickley sandstone is very patchily developed the other rocks in the interval are nearly always siliceous in character, that is, they are most commonly shales tending towards sandy phases. This mass of siliceous strata is of wide distribution and it represents a period of stream activity separating long periods of swamp deposition. The Lower Sewickley sandstone is best developed in Southern Ohio in Meigs and Gallia counties where it coalesces with one above the Redstone coal and with another above the Sewickley coal to form the great stratum that produces the cliffs at Pomeroy and in the adjacent areas. In the remainder of the field the member is most prominent in southern Morgan, eastern Noble, southeastern Belmont, and southern Jefferson counties. In the thinner deposits the Lower Sewickley sandstone is fine to medium in grain but in the thicker ones it is coarse or even pebbly in the basal portion. The bonding components are largely clay matter and iron oxides which give the stone a light gray color in fresh exposures and a drab or brownish tint where much weathered. Where massively developed this sandstone is always conspicuously cross-bedded, the planes being rather closely spaced. Aside from quartz the most abundant mineral is mica. In general appearance this member differs little from others of like nature in the Monongahela Series.

#### Sewickley Coal.

The Sewickley or Meigs Creek coal has fair development over a much larger area than any other coal bed in the Monongahela Series of Ohio. It far surpasses the great Pittsburgh in volume of fuel but is much below that standard in quality of material. The usual position of

the Sewickley coal is from 70 to 90 feet above the base of the Pittsburgh member and from 100 to 120 feet below that of the Uniontown. More directly it lies just above the Lower Sewickley sandstone and shale and immediately below the massive calcareous Benwood member or below the Upper Sewickley sandstone which locally replaces the basal portion of the Benwood. The Sewickley coal is quite unsteady in that it undergoes many changes in thickness, in structure, and in continuity in its extension across the Ohio field. The thickness of the bed varies from one-eighth inch or less to eight feet or more. The latter measurement, however, includes both coal and parting materials as the thickness of the coal alone is seldom over six feet. The structure of the member changes from one locality to another and from a simple bed of coal or bone shale to a composite one made up of coal, clay, bone shale, and shale with diverse arrangement. This member is also subject to "splits" and to secondary lenses of coal appearing both above and below the main bed.

The Sewickley coal is a member of economic importance in Belmont, southern Jefferson, southeastern Harrison, Monroe, southern Guernsey, Noble, eastern Washington, eastern Morgan, and southeastern Muskingum counties. The thickest and purest deposits are found in western Belmont, Noble, north central Washington, and eastern Morgan counties. The Muskingum River marks approximately the western boundary of the productive field. In the remainder of the area in western Morgan, western Washington, Athens, Meigs, Gallia, and eastern Lawrence counties this bed is much impoverished in character and very uncertain in extent. At best it is only a thin stratum of impure coal and in many areas it is absent from the section both through replacement by sandstone and through lack of deposition. Scattered deposits, however, found as far south as Gallia County aid in its correlation.

The Sewickley coal is impure largely through the presence of closely spaced, papery partings of shale that are present throughout the entire thickness of the bed. It is also high in sulphur which is present as pyrite and as organic sulphides. The average content of ash in the Sewickley coal in the Ohio field is approximately 11.60 percent and that of sulphur 4.25 percent. The Sewickley coal is an asset of only local importance at present but upon the exhaustion of the great Pittsburgh member it will increase much in value.

#### Upper Sewickley Sandstone.

The Upper Sewickley sandstone is present only in local areas along the western and southwestern margins of the Ohio field. The materials forming these deposits and also those entering into the associated siliceous shales appear to have been derived from land areas located to the west and to the northwest. The Upper Sewickley sandstone is entirely

absent in a large basin extending over most of Belmont, Jefferson, Harrison, and northern Monroe counties and in smaller areas in southern Monroe, Washington, Morgan, Athens, Meigs, and Gallia counties. The member is best represented in eastern Noble, north central Washington, southeastern Muskingum, and southern Meigs counties. Such deposits usually expand or contract erratically and suddenly between the limits of one to 70 feet. Most commonly the sandstone gives way directly to limestone and calcareous shale but in some localities it passes, by gradation, to argillaceous shale. The form and structure of these deposits indicate that some of them were laid down by streams as delta formations whereas others were originated by currents as shore deposits. The Upper Sewickley sandstone is not distinctive in texture, in structure, or in composition from other sandstones in the Monongahela Series neither is it a unit of stratigraphic or economic importance.

#### **Benwood Limestone.**

The Benwood member is composed of a great series of limestone strata separated by calcareous shale partings. In Ohio, limestone predominates over shale in the northern part of the field and shale over limestone in the southern part. Like other limestones in the Monongahela Series the Benwood is of fresh-water origin. It is by far the richest and most extensive deposit of calcareous matter in the entire system of coal bearing rocks in the Appalachian geosyncline, much surpassing any of the marine beds in the lower part of the Pennsylvanian System. Such deposits are always present on this horizon unless very locally replaced by sandstone. In a broad sense the Benwood member should also include similar limestones and calcareous shales of the overlying Uniontown as the period of general swamp prevalence lasted throughout the time of the formation of both members with only a slight local interruption for the deposition of the Fulton Green shale and for its extension of scattered sandstone lenses. Thus locally siliceous matter was carried into this vast swamp. Moreover, the Fulton member is calcareous to a more or less extent. In large areas the Benwood and the Uniontown limestones coalesce with no evident line of demarkation. In Ohio such conditions are found in all but the northern portion of the Monongahela area. The average thickness of the Benwood member is close to 59 feet and its limits of variation are commonly between 52 and 65 feet. The most typical exposures when uniformity of structure and content of calcium carbonate are considered are in Belmont and Jefferson counties.

#### **Fulton Green Shale.**

Aside from limestone the most conspicuous deposit between the Sewickley coal and the Uniontown coal is a bed of greenish laminated shale which lies about midway in the interval between the coals and which is moderately persistent in the Pan Handle of West Virginia and

in adjacent parts of Ohio. The stratum was named the Fulton Green shale in 1906 by G. P. Grimsley. It is decidedly siliceous and usually calcareous in composition. The coloring pigment appears to be finely divided ferrous carbonate or siderite. In Ohio this member is a definite stratigraphic unit in Jefferson, eastern Harrison, Belmont, and eastern Monroe counties. Beyond this field to the southwest it loses its identity by breaking up into several thin layers, widely separated, by changing to isolated sandstone lenses, or by disappearing completely. The bed has an average thickness of about four feet nine inches and variable limits from 1 to 10 feet. The Fulton member should be considered more of a phase of the Benwood than a distinct unit as it does not mark decided changes in deposition.

#### Uniontown Limestone Member.

Like the Benwood the Uniontown limestone member consists of a series of thin to massive limestones separated by thin to thick shale partings, some places one and some places the other material predominating. On the whole the deposits are more shale than limestone. The Uniontown member is less calcareous than the Benwood but is much the same physically and structurally. The shale partings are light gray in color and clay-like in texture. In some localities where shale predominates the weathered material is highly colored red, pink, or brownish red thus much resembling some of the deposits in the Conemaugh Series. The limestone is light to dark gray on fresh fractures but is nearly white varying to shades of buff on weathered surfaces. Only locally the member occupies all the interval between the Fulton Green shale and the Uniontown coal. In general 10 feet or more of shale and sandstone intervenes between the limestone and the overlying coal. Partings of this kind are also present locally about midway in the interval. The most massive layers of limestone lie either near the top of the member or in the basal portion just above the Fulton Green shale. The Uniontown limestone member is present across the state from Jefferson County on the east to Gallia County on the south. Owing to partial replacement locally by shale and sandstone the deposits of calcareous matter vary from 30 to 60 feet in thickness. The average measurement of the limestones and calcareous shales, composing the member, is close to 40 feet. In most of Ohio there is no justification in separating the Uniontown and Benwood members, both belonging to one series of fresh water deposits.

#### Arnoldsburg Sandstone.

The Arnoldsburg sandstone is not well defined at any place in the Ohio area. Its position in the geological scale is probably marked by local lenses of sandstone and siliceous shale occurring within the Uniontown limestone and from 20 to 30 feet below the Uniontown coal. The best developed lenses of such material are found in Richland Township,

Belmont County, Switzerland Township, Monroe County, and Stock Township, Noble County.

#### Uniontown or No. 10 coal.

The Uniontown is one of the most persistent coal beds in the Monongahela Series of Ohio as it extends from Jefferson County southwestward across Belmont, Monroe, Washington, Morgan, Athens, and Meigs counties to Gallia. Throughout the field the few wants are small and are occasioned mostly by replacement by sandstone. The bed, however, shows great variation in thickness, in structure, and in character. In thickness it varies from a papery film of "mother" coal to a 4-foot stratum of fair quality fuel. In Ohio the Uniontown coal is best developed along Sunfish Creek and its tributaries in Monroe County where it is mined in many places for local needs. Small lenses of mineable coal are also present in Belmont and Noble counties. In general the thickness of coal on the Uniontown horizon is less than one foot. The member is one of the most erratic in structure in the entire Pennsylvanian of Ohio. It may be made up of one, two, three, or even four benches of coal closely or widely spaced. The parting material may be clay, shale, bone shale, limestone, or sandstone. In many places carbonaceous bone shale forms the roof of the coal and not unfrequently the floor also. In many sections such deposits of coal, shale, bone, clay, etc., occupy an interval of five to 10 feet or more. The Uniontown is one of the few coal beds in Ohio that contains a parting of hard limestone. Such deposits are quite local but are distributed over a rather large area. During the Uniontown time the surface conditions favored the deposition of carbonaceous matter over the entire area but they were so locally modified that the deposits changed in general make-up from place to place. On the higher dryer portions, land plants contributed coal, in the shallow waters, algal matter was consolidated with the silts to form bone shale and lime secreting plants caused the formation of limestone and marl, whereas in the deeper quiet waters the land wastes were deposited to form normal shale. About every type of material found associated with coal may be present in one exposure. The bone shales in the roof of the coal are quite frequently highly charged with the casts of ostracods. The outstanding features of the Uniontown coal in Ohio are the persistency of the bed over the entire area, the multiple and the changeable structure of the deposits from place to place, and the complexity of materials entering into the member.

#### Uniontown Sandstone.

The Uniontown sandstone is a bed of no special prominence in Ohio. It has fair development in small areas in western Belmont, northwestern Monroe, southeastern Muskingum, and southern Morgan counties. Elsewhere shaly sandstone and sandy shale are found above the

Uniontown coal. In texture and in composition the member is much the same as other sandstones in the Monongahela Series, that is, the grain is fine to medium, the color is light gray to buff, the bond is argillaceous and ferruginous matter, and the conspicuous mineral aside from quartz is mica. Unless shaly the Uniontown sandstone is massively bedded. In a few localities it coalesces with the Gilboy thus filling most of the interval between the Uniontown and the Waynesburg coals with sandy materials. Its position is directly or not far above the Uniontown coal.

#### **Waynesburg Limestone.**

The Waynesburg limestone named by Stevenson for deposits in Washington and Green counties, Pennsylvania, lies directly or closely below the Little Waynesburg coal and from 10 to 25 feet below the Waynesburg coal. The material is of fresh water origin and the deposits, where typically developed, consist of several layers of light colored limestone separated by partings of light gray shale. The thickness of the member is from four to 15 feet. Limestone is prominent on this horizon only in Belmont and Monroe counties. Elsewhere the lateral representative is a grainy, light to drab calcareous clay, bearing some marly limestone in the basal portion.

#### **Little Waynesburg Coal.**

In Ohio the Little Waynesburg coal, although always thin, is remarkably steady in its extension from Jefferson County on the east to Gallia County on the south, a distance of over 100 miles. The maximum thickness of the bed is less than six inches and the mean measurement not more than one inch. In large areas the member is contracted to a mere film of mineral charcoal. This bed is best developed in Belmont and Jefferson counties where the associated Waynesburg limestone is quite prominent. The conditions giving rise to the Little Waynesburg coal were regional in extent but were short in duration.

#### **Gilboy or Browntown Sandstone.**

The Gilboy or Browntown sandstone, lying between the Little Waynesburg and the Waynesburg coals, is of no consequence as a stratigraphic unit in Ohio. This interval is filled mostly with clay and shale. Deposits of sandstone on this horizon are few in number, local in area, small in thickness, and not unusual in character.

#### **Waynesburg Coal.**

The Waynesburg coal, the youngest bed in the Monongahela Series, extends across the Ohio area from Jefferson County to Gallia County. It is exceptionally steady in the northeastern portion of the field but is wanting in many localities, through replacement by the Waynesburg sandstone, in the southwestern portion. Deposits, however, are present

in every county in which the bed is due. The important area of Waynesburg coal is in Jefferson, Belmont, and eastern Monroe counties where it varies from a few inches to five feet in thickness and where it is mined in many places for domestic fuel. Thick partings are rather uncommon in the Waynesburg coal but thin ones of the papery type are quite closely spaced. On this account the fuel is high in ash. In Belmont and Jefferson counties the Waynesburg coal is closely overlain by the Elm Grove limestone of the Dunkard Series, elsewhere the roof is usually siliceous shale or sandstone.

## THE MONONGAHELA SERIES OF WEST VIRGINIA

By DAVID B. REGER,  
Acting State Geologist of West Virginia.

## Introduction.

The Monongahela Series of the Pennsylvania, or Upper Carboniferous, system of rocks covers approximately 6,541 square miles of territory in West Virginia, of which about 2,817 square miles outcrop at the surface and 3,724 square miles are covered by Permian beds. With the exception of a few square miles in the North Potomac Basin of Preston, Tucker, Grant, and Mineral counties all this large area is situated in the Ohio River drainage basin of the northwestern third of the State. Its position in the standard rock column of the Carboniferous of the State is illustrated by the following table:

Era	System	Series	Group
Paleozoic	Permian	Dunkard	{ Greene Washington
		Pennsylvanian	MONONGAHELA .....
	Conemaugh .....		
	Allegheny .....		
	Mississippian	Pottsville	{ Kanawha New River Pocahontas
		Mauch Chunk	{ Bluestone Princeton Hinton Bluefield
	Greenbrier .....		
	Maccrady .....		
	Pocono	{ Pinkerton Myers Hedges Purslane Rockwell	

## Areal Extent.

In the Ohio River drainage basin the Monongahela Series outcrops in the southern edge of Hancock County; in certain considerable areas in Brooke; in more extensive areas in Ohio where it is partly covered with Permian beds; along the river front and some of the deeper creeks of Marshall there being elsewhere an extensive Permian cover; along



Preston, northeastern Tucker, western Grant and western Mineral it occurs in the high ridges, covering only a few square miles but exhibiting Pittsburgh coal which is often 20 feet thick and which is far in excess of that in the more western counties.

Definite criteria for estimating its original extent before erosion began are not available but there is reason to believe that the present areas do not represent more than two-thirds of its earlier boundaries. Figure 1 shows its present areal extent both exposed and covered.

#### Physiography.

In localities where the Monongahela is fully exposed its topography is distinctive and often may be followed by the eye for great distances. At the base the Pittsburgh Coal occurs in the upper edge of a gently sloping bench held up by hard Conemaugh sandstones. Above the Pittsburgh Coal is a steep slope of variable height depending on the local development of sandstones and limestones, followed by a very narrow bench in which the Redstone Coal occurs. Above the Redstone the hill profile is usually an almost uninterrupted steep slope held in place by the Sewickley, Arnoldsburg and Uniontown Sandstones and the intervening Sewickley, Benwood and Uniontown Limestones, and usually protected by a mantle of the Waynesburg Sandstone of Permian age at the top. In this steep slope the Sewickley, Uniontown and Waynesburg Coals occupy scarcely perceptible benches. In central and southwestern West Virginia, where limestones almost totally disappear from the Monongahela section, this steep slope is more broken by benches.

#### General Stratigraphic and Depositional Features.

The Monongahela Series is composed of sandstones, limestones, shales and coals. In general a limestone bed is followed above by fire clay shale, then by coal, then by sandy shale, with a covering of sandstone. Above the sandstone there may be a brief interval of shale before the next stratigraphic cycle begins. Assuming that each sandstone represents the definite termination of a stratigraphic sub-stage or depositional cycle it is evident that there have been nine such cycles in the history of Monongahela deposition and at the top a tenth is completed by the Waynesburg Sandstone of Permian age. Certain of these stages lack the presence of a distinct coal and in certain others there is an absence of limestone, either regional or local. In such localities there is usually an abundance of red shale. Conglomerates as commonly termed are almost totally absent although some of the sandstones have local occurrences of white quartz pebbles.

The limestones are all of fresh-water origin and contain only minute ostracods, gastropods, annelids and other microscopic evidences of life. Generally these beds are gray, yellow or tinged with red, the structure being amorphous and the quality rather impure due to silica

and alumina. The deposits are thick-bedded with intervening layers of calcareous shale.

The fire clay shales are gray or sometimes green, argillaceous and irregularly fractured, being partly leached of their iron by ancient plants some of the roots and other carbonaceous residue of which still remain. These clays are evidently old soils rather than fire clays.

The coals are of the high volatile, bituminous type, medium hard and blocky in structure, being occasionally cut by irregular mud seams and usually though not always divided into two or more benches by bands of bone or gray shale. Chemically they are low in moisture (1 to 2 percent), fairly low in ash (5 to 8 percent), high in volatile matter (30 to 40 percent), medium in sulphur (1 to 3 percent), fairly low in phosphorus (0.005 to 0.050 percent), and rather low in fusibility of ash (1900 to 2400°F), with a B. T. U. content of 11,000 to 14,500.

The shales overlying the coals are usually grayish-brown, or greenish-gray, fissile, sandy or carbonaceous, and often hold the remains of many coal plants.

The sandstones are sometimes greenish-gray and flaggy but more often gray and massive with sufficient iron to cause them to weather brown. In texture they vary from fine-grained to coarse, the quartzitic matrix being accompanied by rather abundant mica and feldspathic material. In general they are fairly soft.

The clays or shales which lie above the sandstones are usually calcareous and sticky without definite lamination and represent the beginning of a quiet time when erosion and degradation were at a minimum.

From the nature of the alternating beds as well as from the absence of marine fossils it is evident that deep water at no time prevailed during Monongahela deposition. Instead, there were shallow estuaries of great rivers where the water was so predominantly fresh that marine life was impossible, followed by shallow swamps in which carbonaceous material could grow and accumulate for rather long intervals of time. These comparatively quiet stages were later interrupted by depression of the swamps and influx of silt and sand.

All the areas of deposition lay within the watershed of the ancient Appalachian Sea and the sediments unquestionably came from ancient Appalachia, a land lying farther southeast toward the present Atlantic Coast region. Naturally the beds were thicker and coarser along the southeastern margin while farther northwest they thinned away and limestones replaced many of the shales while the sandstones became finer grained and more argillaceous.

There is reason to believe that subsequent warping has much disturbed the conditions which existed in Monongahela time. It is true, of course, that filling in Permian time and later elevation have now transformed the whole territory into solid land but the elevation was

evidently disproportionate in certain regions. In the present Appalachian Geo-Syncline, which extends from the southwestern corner of Pennsylvania southwestward across West Virginia to Wayne County and then enters Kentucky, the lowest depression is near Wileyville, Wetzel County, where the Pittsburgh Coal is only 50 feet above sea-level. In this locality the Pittsburgh Coal apparently exists in good thickness and quality indicating a former region without much depth of water. Only a few miles southwest of Wileyville, however, the Pittsburgh Coal suddenly disappears and southwestward for the next 100 miles along the synclinal axis is not again found in quantity but reappears in Mason and Putnam Counties. This intervening territory, 100 miles in length, comprising most of the counties of Tyler, Pleasants, Wood, Ritchie, Wirt, and Jackson, and parts of Doddridge, Gilmer, Calhoun, and Roane, which must have once been the lowest part of the basin, now has a higher structural level than the Wileyville depression, indicating a much greater rise than occurred at Wileyville.

#### Thickness.

The thickness of the series varies from 250 feet along the Ohio River front to a maximum of slightly more than 400 feet in Monongalia and other counties of the Monongahela Valley. In the North Potomac basin of Grant and Mineral Counties the full thickness is not exposed but in the adjacent region of Maryland it is described by the Maryland Geological Survey as only 245 feet thick. The following table indicates the intervals between principal coals in various counties, starting with

the base of the Pittsburgh and figuring to the base of each succeeding coal:

COUNTY	Pittsburgh Coal	Redstone Coal.	Lower Sewickley Coal.	Upper Sewickley Coal.	Lower Uniontown Coal.	Uniontown Coal.	Little Waynesburg Coal.	Waynesburg Coal.
Ohio	0	25	70	90	175	200	230	250
Marshall	0	40		90		225	275	300
Wetzel	0	40		90		225	275	300
Tyler	0	40				225	275	300
Ritchie	0					200		300
Pleasants	0			90		200		300
Wood	0					200		300
Wirt	0					200		300
Jackson	0					200		300
Mason	0					175		275
Calhoun	0			100		250		350
Roane	0			100		250		375
Putnam	0					200		300
Cabell	0					250		275
Monongalia	0	35	70	100	200	300	360	405
Marion	0	35	70	100	200	300	360	405
Taylor	0	35			200	300	360	405
Harrison	0	30		100	200	290	365	405
Doddridge	0	30			200	300	350	400
Barbour	0	40	75	125	225	275	350	400
Upshur	0	40	80	100	225	275	325	375
Lewis	0	40	80	100	225	275	325	375
Gilmer	0	40	80	100	225	275	325	375
Braxton	0	40	80	100	225	275	325	375
Mineral	0	50	100	125				

The figures of the last column represent the full thickness of the series less the local thickness of the Waynesburg Coal. In Ohio and adjacent counties this is about two feet and in Monongalia and Marion Counties it is five to 10 feet. Elsewhere it is insignificant. The absence of a figure in the table indicates regional absence of the coal but it does not follow that the coals are always present, when figures are given. Many of these represent shale and fire clay horizons which have replaced the coals.

### General Section.

The following general section, prepared by Ray V. Hennen and published in the Monongalia-Marion-Taylor County Report of the West Virginia Geological Survey, illustrates the nature and succession of the Monongahela Series. To Mr. Hennen's section the writer has added certain descriptive terms and the names of members which have been classified in later years:

#### General Section of the Monongahela Series for West Virginia.

	Thickness Feet	Total Feet	Interval Feet
Coal, Waynesburg	5	5	
Shale, gray or red	10	15	
Sandstone, Gilboy, gray or green	35	50	
Coal, Little Waynesburg	1	51	51
Limestone, Waynesburg, gray	4	55	
Shale, gray or red	13	68	
Sandstone, Uniontown, gray or green	35	103	
Shale, Annabelle, brown, 15' to	0	103	
Coal, Uniontown	2	105	54
Shale, gray or red	10	115	
Limestone, Uniontown, gray or red	15	130	
Shale, red or green, with thin sandstones and limestones	44	174	
Sandstone, Arnoldsburg, gray or green	30	204	
Coal, Lower Uniontown	1	205	100
Limestone, Arnoldsburg, 7' to	0	205	
Shale, Fulton Green	5	210	
Limestone, Benwood, gray	65	275	
Sandstone, Sewickley, gray	25	300	
Coal, Sewickley	5	305	100
Sandstone, Lower Sewickley, gray	25	330	
Coal, Lower Sewickley, 2' to	0	330	
Limestone, Sewickley, gray or yellow	43	373	
Sandstone, Cedarville, gray or green, 40' to	0	373	
Coal, Redstone	4	377	72
Sandstone, Weston, gray or green, 20' to	0	377	
Limestone, Redstone, yellow	5	382	
Sandstone, Upper Pittsburgh, gray	15	397	
Shale, Weston, gray	5	402	
Coal, Pittsburgh	8	410	33

#### DESCRIPTION OF MEMBERS.

##### Pittsburgh Coal.

The Pittsburgh Coal, forming the basal member of the series, is generally present where the Monongahela Series occurs in Hancock,

Brooke, Ohio, Marshall, northern Wetzel, Monongalia, Marion, Taylor, Harrison, Barbour, Upshur, Lewis, eastern Doddridge, eastern Gilmer, Braxton, Clay, southern Calhoun, southern Roane, Kanawha and portions of Putnam, Mason, Cabell and Wayne Counties. Also there are outliers in Preston, Tucker, Grant and Mineral. Elsewhere it is largely, if not entirely, absent,

Its greatest thickness is in Mineral County where it is nearly 20 feet. In Monongalia and other counties of the Monongahela Valley it is six to 12 feet. In Ohio and other counties of the northern pan-handle it is about five feet. In the counties south of the barren territory it varies from one to eight feet. In the regions of greater thickness there are usually two or three thin bands of bone near the middle. Otherwise it is generally free from partings.

#### **Weston Shale.**

The Weston Shale, overlying the Pittsburgh Coal, is a gray, sandy bed varying from five to 10 feet thick, used for brick at Weston, Lewis County.

#### **Upper Pittsburgh Sandstone.**

The Upper Pittsburgh Sandstone is a gray, massive, rather coarse, soft stratum, varying in thickness from five to 50 feet. Generally it contains mica and feldspathic material, being prominent in Monongalia and other counties of the Monongahela Valley and making a great cliff in the southern counties.

#### **Redstone Limestone.**

The Redstone Limestone, so called from Redstone Creek in Fayette County, Pa., is a yellow, hard, amorphous stratum, five to 10 feet thick and largely confined to the counties of the northern pan-handle and those of the Monongahela Valley. Southward it thins out and disappears. It contains some microscopic fresh-water shells.

#### **Weston Sandstone.**

The Weston Sandstone, is a gray or greenish bed five to 30 feet thick and largely confined to the vicinity of Weston, Lewis County, where it forms a noticeable lens in the series.

#### **Redstone Coal.**

The Redstone Coal, belonging 20 to 50 feet above the Pittsburgh, is a bed of quite excellent high volatile coal, varying in thickness from 0 to 6 feet. Usually it is entirely free from bone or shale partings but irregular, transverse mud seams are not uncommon. In certain areas it is thin or entirely lacking but there are large bodies of it in Monongalia, Harrison, Barbour, Upshur and Lewis Counties.

#### **Cedarville Sandstone.**

The Cedarville Sandstone, belonging almost immediately over the Redstone Coal, is a gray or greenish-gray, micaceous and fine-grained

deposit, sometimes massive but more often shaly. In many localities it is replaced by shale or limestone but in Gilmer County where it was named it is a prominent ledge.

#### **Sewickley Limestone.**

The Sewickley Limestone, belonging slightly above the Redstone Coal from which it is sometimes separated by a bed of shale or by the lenticular Cedarville Sandstone, is a body of thick-bedded calcareous material, amorphous and rather firm on fresh exposure but inclined toward eventual disintegration because of included argillaceous matter. Its color is gray or dull yellow and it seldom if ever attains the qualities of a good limestone, due to the presence of silica and alumina. Layers of calcareous shale between the thick beds of lime are quite common. It is prominent in the northern pan-handle and in Monongalia, Marion and other counties of the Monongahela Valley, being often 40 feet thick. Farther south it thins out and disappears from the section. It usually contains microscopic fresh-water shells, the study and classification of which has not been concluded.

#### **Lower Sewickley Coal.**

The Lower Sewickley Coal, belonging 60 to 90 feet above the Pittsburgh is a lenticular and generally worthless deposit largely confined to the northern pan-handle, and seldom exceeding two feet in thickness. In the Monongahela Valley it is almost totally absent.

#### **Lower Sewickley Sandstone.**

The Lower Sewickley Sandstone is a gray or greenish-gray bed, sometimes massive but often shaly or entirely absent from the section. When present it belongs almost immediately below the Sewickley Coal and is a replacement of all or part of the Sewickley Limestone. It is found in certain parts of the Monongahela Valley.

#### **Sewickley Coal.**

The Sewickley Coal, coming 80 to 120 feet above the Pittsburgh, is the second seam of the series in point of present commercial importance. It varies in thickness from 0 to six feet, being a rather hard blocky coal, high in volatile matter, and being usually separated into two benches by a shale or bony parting in the lower half. In Monongalia and Marion Counties where it is mined extensively it is often five or six feet thick and from these counties it extends westward through the covered region of northern Wetzel County and southern Marshall and emerges above drainage in northern Marshall and Ohio Counties where it is two or three feet thick. South of the counties named it is seldom found in minable thickness.

#### **Sewickley Sandstone**

The Sewickley Sandstone, coming a few feet, or just above the Sewickley Coal, is perhaps the most prominent ledge of the Monon-

gahela series. In the northern pan-handle it is usually thin and shaly but in the Monongahela Valley it is a yellowish-gray, massive deposit of rather durable character and farther south in Lewis, Braxton, Gilmer, Calhoun and Roane Counties it carries rather abundant white quartz pebbles.

#### Benwood Limestone.

The Benwood Limestone, belonging just above the Sewickley Sandstone, is a gray or dull yellow, thick-bedded deposit of limestone with intervening beds of calcareous shale. Usually it is sandy and argillaceous and inclined toward disintegration. In the regions of its occurrence it varies from 20 to 65 feet in thickness, being quite prominent in the northern pan-handle and having derived its name from Benwood, Marshall County. In the Monongahela Valley it commonly occurs as far south as Harrison County but beyond that locality it thins out and disappears. It carries a sparse fresh-water fauna of microscopic shells.

#### Fulton Green Shale.

The Fulton Green Shale is a persistent bed of bright green, argillaceous material seldom more than five feet thick but conspicuous on account of its color. It is especially evident in the northern pan-handle where it is of value for stratigraphic purposes. The chemical and petrographic details of its coloring have not been fully determined.

#### Arnoldsburg Limestone.

The Arnoldsburg Limestone (new) is a buff, hard stratum occupying most of the interval between the Fulton Green Shale and the Arnoldsburg Sandstone in the northern pan-handle region of West Virginia and belonging just below the horizon of the Lower Uniontown Coal. The following section, measured by the writer in company with Mr. A. B. Brooks, Park Naturalist of Oglebay Park, was observed at the falls of Waddles Run  $1\frac{1}{2}$  miles east of Greggs Village, Ohio County, and indicates the relationship of this limestone:

- |  |     |
|--|-----|
| 1. Sandstone, Arnoldsburg, greenish-gray, making falls (930'B) ..... | 15' |
| 2. Limestone, Arnoldsburg, buff, hard .....                          | 15  |
| 3. Shale, Fulton Green .....   | 5   |
| 4. Limestone, Benwood, visible in road to westward ..                |     |

At certain other neighboring exposures a shale interval occurs between the Arnoldsburg Limestone and Arnoldsburg Coal and this interval would represent the horizon of the Lower Uniontown Coal. The Arnoldsburg Limestone, deriving its name by association with the Arnoldsburg Sandstone, therefore belongs directly between the Fulton Green Shale and Lower Uniontown Coal.

#### Lower Uniontown Coal.

The Lower Uniontown Coal, belonging immediately under the Arnoldsburg Sandstone and approximately 200 feet above the Pittsburgh Coal, is a mere marker which is present only in restricted localities and is always too thin for mining.

#### Arnoldsburg Sandstone.

The Arnoldsburg Sandstone, belonging just above the horizon of the Lower Uniontown Coal, is usually a greenish-gray, fine-grained micaceous deposit, varying from 10 to 40 feet in thickness, but in Calhoun County where it was named it is coarse, gray and pebbly. At various localities, notably at Fairmont, Marion County, it has been quarried for building purposes.

#### Uniontown Limestone.

The Uniontown Limestone, coming between the Arnoldsburg Sandstone and the Uniontown Coal and often associated with red shales, is of variable occurrence and texture, being sometimes massive and sometimes shaly or nodular and varying in color from gray to red. In northern West Virginia the thickness may be 20 or 25 feet but it decreases and is replaced by shale farther south. It holds occasional microscopic fresh-water shells.

#### Uniontown Coal.

The Uniontown Coal, belonging slightly above the Uniontown Limestone and 200 to 275 feet above the Pittsburgh Coal, is a thin but quite persistent bed, occurring in the northern pan-handle and the Monongahela Valley and recurring westward in Doddridge, Pleasants and other counties and southward into Calhoun and Roane. Often it is only one foot or less in thickness but at some localities it reaches four or five feet, being usually split into two or three benches in such cases. In some localities it has been mined for local domestic fuel.

#### Annabelle Shale.

The Annabelle Shale, lying between the Uniontown Coal and the Uniontown Sandstone, is a greenish-brown, sandy stratum, 0 to 15 feet thick. At Annabelle, Marion County, it has been used for the manufacture of brick.

#### Uniontown Sandstone.

The Uniontown Sandstone, coming a few feet above the Uniontown Coal, is usually greenish-gray, micaceous and often shaly with a thickness of 10 to 30 feet in the northern pan-handle and the Monongahela Valley but farther south it becomes bolder and in certain parts of Calhoun and Gilmer Counties it is a massive gray, cliff, 40 to 50 feet thick, containing many white quartz pebbles.

#### Waynesburg Limestone.

The Waynesburg Limestone, together with shales of variable thickness, occupies the interval between the Uniontown Sandstone and Little Waynesburg Coal. In the northern pan-handle and in Monongalia and other counties of the Monongahela Valley where it principally occurs the limestone varies from one to 10 feet in thickness, being usually gray and rather hard and containing a considerable amount of silica and alumina. In southern West Virginia it is seldom, if ever, found.

#### Little Waynesburg Coal.

The Little Waynesburg Coal, belonging between the Waynesburg Limestone and Gilboy Sandstone, is a thin marker usually less than one foot thick and of only occasional occurrence, being found at a few points in the Monongahela Valley and being infrequently noted in oil well records farther west. In southern West Virginia it appears to be absent.

#### Gilboy Sandstone.

The Gilboy Sandstone, so named because of its occurrence in the Gilboy cut of the Baltimore and Ohio Railroad in Marion County, is a gray or brown, massive, micaceous ledge, occasionally becoming green and shaly in some localities and having a thickness of 10 to 50 feet. It is prominent in many portions of the Monongahela Valley and has been traced into the southern counties. In the northern pan-handle it is not so thick or massive but may be recognized without difficulty.

#### Waynesburg Coal.

The Waynesburg Coal, forms the Upper Member of the Monongahela Series and derives its name from Waynesburg, Greene County, Pennsylvania. It is a soft, glossy, multiple-bedded deposit, usually having two or more heavy partings of bone or gray shale, and sometimes attaining a total thickness of 10 or 12 feet. If carefully separated from the shale and bone the coal is of good quality, suitable for steam and domestic use. Its principal region of occurrence at outcrop in West Virginia is in Monongalia and Marion Counties of the Monongahela Valley and in Marshall, Ohio, and Brooke Counties of the northern pan-handle. Farther south it has been noted in Jackson County, and in Wetzel it is frequently recorded in well borings. South of Marion and Wetzel Counties, however, it appears to be worthless, being too thin or too impure for mining in the few localities where it has been noted. In Monongalia County it has been mined rather extensively both for local domestic use and for commercial shipment.

An unusual feature of the Waynesburg Coal is the presence of fossil cockroaches in a shale parting near the top of the bed. These were studied intensively in Monongalia County by Mr. C. L. Eakin, being later identified by Prof. Samuel Scudder as published on page 14, Bulletin 124, U. S. Geological Survey, and still later republished by Dr.

I. C. White with additional comment on page 123, Vol. II, West Virginia Geological Survey. The collection consisted of 56 species distributed among five genera as follows:

Etoblattina lata	Etoblattina expugnata
sagittaria	obatra
mediana	imperfecta
ovata	secreta
debilis	invisa
balteata	occulta
patiens	defossa
mucronata	recidiva
detecta	Gerablattina inculta
exigua	perita
residua	diversinervis
funeraria	cassvici
expuncta	abdicata
aperta	concinna
eakiniana	uniformis
accubuta	permanenta
expulsata	permacra
gratiosa	eversa
macerata	deducta
immolata	radiata
mactata	lata
communis	rotundata
exsecuta	ovata
arcta	Anthracoblattina virginiensis
praedulcis	Poroblattina gratiosa
angusta	fossa
macilenta	complexinervis
rogi	Petrablattina hastata

#### Economic Aspects.

In its economic phases the Monongahela Series is vastly important. Its four commercial coals, Pittsburgh, Redstone, Sewickley, and Waynesburg, have been the principal factor in the commercial development of northern West Virginia, as well as of the adjacent region of western Pennsylvania. Its limestones and rich calcareous shales afford fertility to the soils of the Monongahela Valley and the northern pan-handle and the limestones have been used extensively for road metal and other construction purposes. Some of the sandstones are of pleasing architectural texture and have been used for building and engineering structures. In regions where the shales are not too calcareous they are suitable for the manufacture of brick and tile.

## THE MONONGAHELA SERIES OF PENNSYLVANIA

By GEO. H. ASHLEY,

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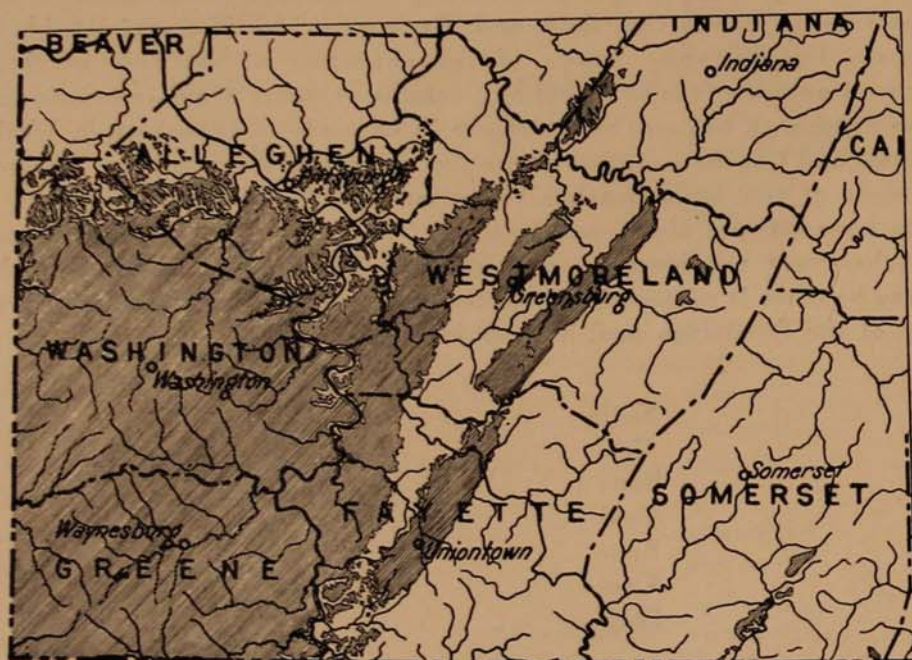
**Extent.** If a line were plotted on a map of Pennsylvania, enclosing the farthest outcrops of the Monongahela series, it would include a large part of the State, or approximately 16,500 square miles. The Monongahela series occupies a large area in the southwestern corner of the State; it is present in the Wellersburg or Georges Creek basin at the eastern edge of the coal field, and it occurs in the Anthracite fields of eastern Pennsylvania. Study of the character of the coal at these farthest outposts fails to reveal any definite evidence of shore conditions. The Pittsburgh bed was very definite in its mode of deposition in Washington and Greene counties where the deposit is very typical. The bed consists of two main benches separated by a bearing-in bench with a thin bone parting above and below it. Of course, the top and bottom benches vary considerably in thickness. The relative position of the three benches is extremely characteristic. The following section is typical of the Pittsburgh coal in Washington County:

	Inches
Shale .....	..
Coal .....	48
Bone .....	1
Coal .....	4
Bone .....	$\frac{1}{2}$
Coal .....	38
Clay .....	..

This regular occurrence in the three benches of coal is characteristic in the western part of Fayette County, but in the eastern part of the county the partings increase in number and thickness, and the bed often contains many distinct partings which do not seem to have a definite position in the bed. This same depositional characteristic is very obvious in Westmoreland County. In the western part of this county the Pittsburgh bed is more or less regular in its physical habit, but in the Latrobe basin, particularly in its northern extremity, extra partings come in which are not at all characteristic of the typical Pittsburgh bed. Farther north, in Indiana County, where the Pittsburgh bed appears for the last time, its physical character is hardly recognizable because the position of the partings has changed so completely. The bed maintains its thickness, however, through the addition of shale partings.

In the outlying area of the Pittsburgh coal of Ligonier Valley of Westmoreland County, the bearing-in bench with its top and bottom partings is present in some mines. In others it is entirely absent.

Another persistent parting appears in the upper part of the bed which splits it into four distinct benches instead of three. Another outlying area of the Pittsburgh coal occurs in southern Somerset County in the vicinity of Meyersdale and Pine Hill. In this area the deposition of the Pittsburgh bed was so irregular that it has been impossible to cite a typical section. The irregular thickness, the occurrence of shale and bone partings at varying positions within the bed and the presence of much bony coal locally, certainly indicates that the deposition was



AREA UNDERLAIN BY MONONGAHELA GROUP.

Fig. 2.

somewhere near the edge of the original coal swamp. In the Wellersburg basin of southern Somerset County, where a small patch of Pittsburgh coal occurs in the hilltop, the bed is even more irregular in its physical character. These examples of irregularity of deposition which is not characteristic of the Pittsburgh bed in southern and southwestern Pennsylvania have been cited to suggest that the outlying areas of the Pittsburgh coal in Pennsylvania indicate that marginal deposition was beginning. Whether or not this marginal deposition indicates the possibility that the Pittsburgh bed was not deposited far beyond its present limits, or whether the irregular deposition characteristics were only local can never be proven. The Pittsburgh may, or may not, have extended clear across Pennsylvania to be connected with the Anthracite fields. It is certain, however, that the Pittsburgh bed does not show any of the deposition irregularities in the vicinity of Pittsburgh, as it does

on the eastern margin of the field. At Pittsburgh erosion seems to have removed the Pittsburgh bed where it was yet typical. The probability is that the Pittsburgh bed originally extended far north of Pittsburgh.

The probable original area in Pennsylvania was between 16,500 square miles and the estimated original total extent of the coal fields, or a total of 38,000 square miles. If the rocks were unfolded, this area would be 44,000 square miles.

**Thickness.** The thickness of the series in southwestern Pennsylvania ranges from 260 feet to about 400 feet, apparently decreasing in thickness from the southwest corner of the State, toward the north and east as judged by the fact that where the full thickness is exposed in northern Washington County, Pennsylvania, it is 260 feet thick. A similar thickness is characteristic of it in the Georges Creek coal field of Maryland. On the other hand the full thickness of nearly 400 feet occurs in the Irwin basin of Westmoreland County. The exact thickness of the Monongahela in the Anthracite region is not known. If David White, of the United States Geological Survey, is correct in placing the Pittsburgh bed about at the horizon of the Tracy bed, and the Waynesburg bed about at or above the Lewis bed, then the Monongahela is 1,300 or 1,400 feet thick in the Southern Anthracite Field.

Lack of knowledge makes it impossible for us to determine positively that the Monongahela series once extended far from the bituminous field of western Pennsylvania to the beds of similar age in the anthracite fields. Evidence is much more complete for the lower beds and indicates with some degree of probability that the lower beds and coals (of Allegheny age) were more or less continuous across this present wide break. This probability lends credence to the idea that the upper beds also carried across.

**Composition (general).** The Monongahela group differs from other groups of the Coal Measures of Pennsylvania in that it contains a large percentage of limestone. Some sections are more than one-half limestone. In others the limestone is confined mainly to the middle part of the section, and is separated into a number of thin beds by shale. The origin of the limestone is not clear. Most of limestones are nonfossiliferous. None of them are pure and some of them are very impure, containing 5 to 8 percent silica, 1 to 8 percent of alumina, and 2 to over 20 percent magnesia. The occurrence of sandstone in this series of western Pennsylvania so far from the nearest high land is a mystery. In the main these sandstones are thin bedded and as stated above change in character within short distances. The Monongahela is further distinguished from formations above and below by its richness in coal. There are four workable beds in the series in western Pennsylvania, and a few minor beds. The Pittsburgh bed at the base is the only one which is persistently workable. Some sections contain one or more massive sandstones, and others almost no sandstone. With the exception

of the Pittsburgh coal, the other coals and rocks appear to be extremely variable. For example, the Pittsburgh sandstone is hard and massive and 35 feet thick at Fair Haven. One mile north it is almost lacking. A mile farther north it is represented by 30 feet of interbedded sandstone and shale, and three miles north it is 60 feet thick including a small amount of interbedded shale. Because of these irregularities the intervals between the several coals and other members is quite variable within short distances. In the Anthracite fields no limestone appears, and sandstone predominates, at least in the lower part of the section, forming more than half the section at Pottsville.

At least two widespread erosional unconformities occur in the Monongahela series. The one at the base of it, beneath the Pittsburgh coal, is very widespread and definite. In some localities the clay and a few feet of shale which normally underlies the Pittsburgh has been removed and the coal is resting directly upon a shale floor. Channels in the old erosion of surface have been filled with carbonaceous material which was later formed into coal. These channels are particularly typical of the Pittsburgh bed on the boundary line between Allegheny and Washington counties. Drill holes in Greene County have shown the presence of this erosional unconformity and there is reason to believe that it is present throughout the entire southwestern part of Pennsylvania. A typical unconformity appears at many localities at the base of the Pittsburgh sandstone. In some places this unconformity is as much as 20 feet. Locally the Redstone coal rests upon an unconformity. This unconformity, however, is not as well defined as the one beneath the Pittsburgh bed. The unconformity at the base of the Sewickley coal is severe in numerous localities, and in quite large areas the Sewickley sandstone rests directly upon the Redstone coal. No distant unconformities have been noticed in the Washington group which overlies the Pittsburgh. It is quite unusual to find such numerous unconformities in rocks which contain a coal bed which seems to be typical of deposition in slowly sinking rocks.

**Distribution.** Except in the Irwin-Elders Ridge syncline the occurrence of the series in southwestern Pennsylvania is confined to the area south of the latitude of Pittsburgh. The series occurs in an almost solid area from the western boundary of the State and just south of Pittsburgh to western Westmoreland and Fayette counties. Small areas are present in the Greensburg basin, and a larger area in the Uniontown-Connellsville-Latrobe syncline. East of that the series has been removed except from very small areas in the Ligonier basin. There is one hilltop of a few acres in northern Somerset County, and larger areas in the Elk Lick and Wellersburg basins of southern Somerset County. Here the series is thinner than it is west of Monongahela River. In the Anthracite region rocks of supposedly Monongahela age

are found mainly in the Southern Anthracite Field, and in the center of a few synclines.

**Physical conditions of origin, etc.** Life remains, and the presence of much fresh-water limestone, indicate that the rocks of the Monongahela of Pennsylvania, were laid down in fresh water. The Pittsburgh coal at the base of the series was clearly laid down on a surface roughened by subareal erosion. In places this coal is abnormally thick due to swamps which started early in some of these old erosion channels. So far as is now known the Pittsburgh bed was continuous in all of southwestern Pennsylvania within the limits of its present farthest outcrops; it had formerly been thought that the Monongahela was caught in the hilltops of the Broad Top field and the Wilmore syncline in Cambria County. It has since been determined that in that eastern edge of the soft coal field the Conemaugh group is much thicker than farther west, and that the coal correlated with the Pittsburgh is undoubtedly a coal in the upper half of the Conemaugh.

**Detailed contents.** This group or series in Pennsylvania has been so thoroughly studied by the Second Geological Survey of Pennsylvania, and by members of the United States Geological Survey in the mapping for folios, that there is little new information regarding its members in this State. The following section was measured near Brownsville by I. C. White.\* It is fairly typical of the group on Monongahela River.

**Section of Monongahela Group near West Brownsville.**

Coal, Waynesburg:	Ft.	In.	Ft.	In.
Coal .....		10	}	3
Clay .....		3		
Coal .....	2	6		
Shale and sandstone .....			45	
Shale, bituminous Little Waynesburg coal . . .			1	6
Limestone, Waynesburg .....			10	
Sandstone, shaly .....			40	
Coal, Uniontown .....			3	
Shale and sandstone .....			28	
Limestone, with thin shale .....			88	
Coal, Sewickley .....				Blossom
Sandstone, shaly .....			32	
Limestone .....			30	
Shale .....			20	
Coal, Redstone .....			1	
Sandstone and Shale .....			45	
Coal, Pittsburgh, roof:				

\*White, I. C., Stratigraphy of the bituminous coal fields of Pennsylvania, Ohio, and West Virginia: U. S. Geol. Survey Bull. 65, page 45.

Coal .....		3	}	2	6
Clay .....		3			
Coal .....	1				
Clay .....	1				
Coal, Pittsburgh, main bench .....				7	
				<hr/>	
				368	7

The following composite of three sections measured recently southwest of Irwin by M. E. Johnson, shows the composition of the group in the Irwin basin where the thickness is close to the maximum.

**Composite Section of the Monongahela Group Southwest of Irwin.**

	Thickness		Total	
	Ft.	In.	Ft.	In.
Coal, Waynesburg .....	2	5	2	5
Clay .....	1		3	5
Shale, brown, soft .....	8		11	5
Coal, shale .....		6	11	11
Clay .....	3		14	11
Shale, sandy .....	7		21	11
Clay .....	2	6	24	5
Shale .....	4		28	5
Sandstone .....	3		31	5
Shale, sandy .....	5		36	5
Concealed .....	17		53	5
Limestone, gray, weathers yellow .....	4		57	5
Concealed .....	5		62	5
Sandstone, gray, thin-bedded .....	5		67	5
Concealed .....	5		72	5
Sandstone, greenish-yellow, thin-bedded ..	10		82	5
Concealed .....	27		109	5
Limestone, cream-colored .....	6		115	5
Concealed .....	4		119	5
Shale, greenish-gray to greenish-yellow ..	11		130	5
Limestone beds, gray and yellow .....	12		142	5
Concealed .....	17		159	5
Shale, greenish-yellow .....	3		162	5
Clay (partly concealed) .....	10		172	5
Limestone .....	6		178	5
Sandstone and Shale, inter-bedded .....	12		190	5
Limestone .....	6		196	5
Shale, limy, "cement rock" .....	4		200	5
Limestone beds with some inter-bedded shale and clay .....	17		217	5

Concealed .....	12		229	5
Limestone .....	3		232	5
Clay, yellow .....	2		234	5
Concealed .....	6		240	5
Sandstone, thin-bedded .....	8		248	5
Shale .....	4		252	5
Coal and carbonaceous shale, "Bench" .....	2	6	254	11
Shale, yellow .....	4		258	11
Sandstone, gray, shaly .....	4		262	11
Shale .....	2		264	11
Limestone beds .....	10		274	11
Clay, olive-green .....	15		289	11
Limestone .....	2		291	11
Clay .....	2		293	11
Shale .....	5		298	11
Sandstone, yellow, massive-bedded, badly cross-bedded, Sewickley .....	20		318	11
Clay, gray, with limestone nodules .....	3		321	11
Clay, yellow .....	2	6	324	5
Limestone, light-gray .....	1	8	326	1
Clay .....	4		330	1
Sandstone, hard, gray, close-grained .....	3		333	1
Shale, sandy, and occasional thin sandstone beds .....	40		373	1
Shale, dark gray .....	10		383	1
Coal and partings, Pittsburgh .....	9		392	1

The characteristic members of the group are as follows:

**Waynesburg coal.** This coal bed, which forms the top of the series, is fairly persistent in western Pennsylvania, though not everywhere of workable thickness. It is usually double, and 5 to 10 feet thick in Greene County and western Fayette County. Northward it thins to 3 feet or less, and is split by clay beds as it is everywhere to the south.

**Iron ore.** Locally the shale under the Waynesburg coal contains sufficient nodular iron ore to have been mined, for example, in Morgan Township, Greene County.

**Little Waynesburg coal.** This is a thin and noncommercial coal or black shale 25 to 40 feet below the Waynesburg bed, and is noted in many sections.

**Waynesburg limestone.** Directly below the Little Waynesburg coal is found distributed widely a dark gray to cream-colored shaly limestone 8 to 16 feet thick, which thins out southward.

**Uniontown sandstone.** This sandstone occurs locally as a massive, gray sandstone 60 to 75 feet below the Waynesburg coal. In places it

is fine grained and hard, and produces a notable effect on the topography.

**Uniontown coal.** This coal lies 80 to 110 feet below the Waynesburg coal, and though locally 3 feet thick, it is usually less than one foot thick or lacking. It is locally represented by black shale and coal containing an abundance of fish remains.

**Benwood limestone.** This is a general name given to the series of limestones between the Uniontown and Sewickley coals. In places the interval of 100 to 160 feet is almost entirely filled with limestone. The characteristic Benwood consists of a number of limestone members separated by limy shale. Many sections of the Benwood are given in the Pittsburgh and Greensburg atlas parts recently published by the Pennsylvania Survey. The Benwood varies from a pure, blue-gray limestone to dark gray, carbonaceous and soft arenaceous limestone. Local names have been given to some of the more persistent benches or members, as follows:

**Uniontown limestone.** The top, 10 to 15 feet, of the Benwood limestone is fairly well separated from the rest of the limestone below. It is an impure, buffish, magnesium limestone, suitable for the manufacture of natural cement. It appears to be the only limestone member of the Benwood limestone that reaches the Kanawha region in West Virginia. In Washington County it is 30 to 40 feet thick, and occurs just below the Uniontown coal. Four layers of limestone have distinguishing characteristics. The top bed is a brownish red limestone weathering soft and yellow. Its outcrop is usually marked by brown limestone nodules. One foot below this bed is a blue limestone weathering to a white clay through which the blue shows. Sixteen to 18 feet lower is a limestone one foot thick, characteristically spotted. Ten feet under that is a solid limestone one foot thick containing hard particles that resist weathering, making raised, pimple-like protuberances on the weathered surface of the rocks. These distinctions, which have been noted particularly in Washington County, have proved very serviceable in detailed structural mapping where the structure is to be represented by 5-to 10-foot contours.

**Bulger limestone.** Underlying the Uniontown limestone, and separated from it by 15 or 20 feet of coarse, calcareous shale, about 60 feet above the Sewickley coal, is a limestone one to two feet thick of a solid to muddy brown color and uneven to smooth fracture. It is quite persistent, and has also proved a good key horizon for use in detailed structural mapping.

**Dinsmore limestone.** Below the Bulger limestone is 20 feet of shale, olive-green on top and red or yellow below. Under this is four feet of shales and limestone. The limestone is in beds four to eight inches thick, of a creamy, white color, separated by calcareous shale that weathers out and leaves the limestone ledges in bold relief. This

limestone is the most persistent feature of this part of the Monongahela series. It is not certain that these members can be distinguished throughout the entire area. The names given have been applied in Washington County where these distinctions have been noted and have proved of great service in structural mapping.

**Sewickley sandstone.** While in many places only limestone and shale occur between the Uniontown and Sewickley coals, in some places a flaggy to massive, often double, sandstone 20 to 60 feet thick occurs just above the Sewickley coal, as at Big Falls on the Monongahela River.

**Sewickley coal,** (Mapleton coal of oil and gas drillers). The Sewickley coal directly underlies Sewickley sandstone; it is unimportant in northwestern Washington County, being only four to eight inches thick, or less, but increases to five or six feet in southeastern Greene County. In places it is split until it occurs within a total space of 20 to 30 feet, often appearing as two benches separated by a maximum of 17 feet of sandstone. Some question has been raised as to whether the coals may not be at two horizons, and whether the upper one should not be called the Upper Sewickley, the position of which is above the Sewickley sandstone and under the Benwood limestone; the other comes under the Sewickley sandstone and just over the Fishpot limestone. Locally the sandstone between thins out and they come together, as at Uniontown. The members of the U. S. Geological Survey have not been able to differentiate an Upper and Lower Sewickley coal, although they recognize such a possibility.

**Fishpot limestone.** The interval of 40 to 60 feet between the Fishpot limestone and the Redstone coal is usually occupied by a sandstone and one or two benches of limestone separated by shale. The limestone, which has been called the Fishpot, is often 20 to 30 feet thick.

The shaft sections in the Uniontown syncline show a coal 118 to 142 feet above the floor of the Pittsburgh coal that has a maximum thickness of two feet. A coal this distance above the Pittsburgh probably corresponds to the Sewickley coal in the basins farther west, but it should be remembered that in the Uniontown syncline the interval between the Pittsburgh and Redstone syncline is over 80 feet.

**Redstone coal.** A small bed of coal 30 to 85 feet above the Pittsburgh is locally three to five feet particularly in parts of Fayette and Somerset counties. Near Madison Station, Westmoreland County this bed is six feet nine inches thick.

**Redstone limestone.** This limestone, 10 to 20 feet thick, occurs directly under the Redstone coal. It is a persistent, fresh-water, compact, brittle limestone. It appears to be thickest where the Redstone coal is thin and vice versa.

**Pittsburgh sandstone.** Where the Redstone limestone is prominent it is usually underlain by shales down to the Pittsburgh coal. When it

is thin or absent the interval is occupied largely by a coarse, massive, often double sandstone 25 to 70 feet thick.

**Pittsburgh coal.** The Pittsburgh coal is best known and probably the most valuable mineral deposit in the world. Its estimated area in Pennsylvania is 2,126 square miles, which, allowing an average thickness of seven feet, gives 9,641,000,000 tons as the original content of coal in this bed in Pennsylvania. The Pittsburgh bed is persistent everywhere it occurs in Pennsylvania. The Pittsburgh bed was laid down on an irregular surface and responds to these irregularities by an increased thickness at the bottom of the bed. These irregularities, however, are rather local so that as a whole the bed is strikingly regular. For the most of the field in Pennsylvania the bed consists of a "main" bench overlain by the "main" and that in turn by the roof coal. The roof coal ranges from 12 inches to seven feet in thickness. It is usually shaly, or much split by partings, and irregular clay masses, so that it has usually been considered as unworkable. The "main" coal over in Monongahela River district occurs in four persistent benches. The Uppermost, called the "breast" coal, is thickest and ranges from two to 10 feet thick, averaging over three feet. A  $\frac{1}{4}$ -inch parting, underlies it. The "bearing-in" bench, three to six inches thick, underlies this thin parting, and another  $\frac{1}{4}$ -inch parting separates it from the "brick" bench, which is about one foot thick. The bottom bench, 12 inches to 20 inches thick, is separated from the "brick" coal by a thin parting, which is locally absent. The breast or main coal bench is the most valuable and important part of the bed. It is two feet thick in Ohio; it averages about three feet at Pittsburgh, six feet at Brownsville, and it increases to 10 feet in the Georges Creek region of Maryland. A few inches at top, the breast coal is harder than the rest, is often cannelly and frequently bony and high in sulphur. This streak locally carries fish remains. A thin parting locally occurs near the middle of this bench, especially in the northwestern part of the field. The bearing-in bench, which, in the old days of hand mining, was used to "bear-in", or start mining; is a remarkably regular feature of the bed, especially with its thin shale partings above and below. These parting are usually mottled gray, from  $\frac{1}{4}$  inch to one inch thick. Toward the south boundary of the State they become bony and less conspicuous. The coal in this bench is bright and pure, and three to six inches thick. The brick coal, named from the brick-like shape of the blocks into which it mines, is a foot or less thick. The parting between this and the bottom bench is often inconspicuous and sometimes lacking. The bottom bench, 12 inches to two feet thick, is usually impure, and is only locally mined because of its impurities. Where the coal has thickened in erosion channels, the increased thickness is in the bottom bench. The entire bed is about five feet thick near Pittsburgh. The thickness gradually

increases southward to eight feet, and range from six to eight feet in much of Greene and Fayette counties.

**Monongahela series in Anthracite fields.** The supposed Monongahela of the Southern Anthracite field is reported to be 1,380 feet thick or more, if we accept Mr. White's correlations and assume that the Tracy bed is about the equivalent of the Pittsburgh and the Lewis bed not far below the position of the Waynesburg coal. A section from the Pottsville basin given by the Second Geological Survey of Pennsylvania\* is as follows.

**Section of Pottsville Basin.**

	Rock Feet	Coal beds Feet	Total Feet
Lewis coal .....		8	8
Interval .....	210		218
Spohn coal .....		8	226
Interval .....	210		436
Palmer coal .....		3	439
Interval .....	263		702
Charlie Pot coal .....		3	705
Interval .....	78		783
Clarkson coal .....		7	790
Interval .....	83		873
Selkirk coal .....		7	880
Interval .....	120		1,000
Leader coal .....		3	1,003
Interval .....	45		1,048
Peach Mountain coal .....		5	1,053
Interval .....	60		1,113
Coal bed .....		3	1,116
Interval .....	58		1,174
Little Tracy coal .....		6	1,180
Interval .....	198		1,378
Coal bed .....		2	1,380

It is quite possible if not probable that later work may require some revision of this section, but this is the only section now available on the upper beds of the Anthracite fields.

\*Pennsylvania Second Geol. Survey, Ann. Rep. 1885, p. 329.

The lower part of this section is shown more in detail in the shaft section at the Pottsville Colliery.\*

Section at Pottsville Colliery.

	Feet	Inches
Gray sandstone .....	13	0
Blue slate .....	15	0
Coal bed .....	4	0
Slate .....	9	0
Sandstone .....	24	0
Slate and sandstone .....	3	4
Sandstone .....	17	3
Slate .....	6	3
Coal bed, Little Tracy .....	2	2
Slate .....	6	0
Slate and sandstone .....	7	1
Gray rock .....	64	3
Slate .....	16	0
Coal and slate .....	3	6
Coal bed, Tracy or Big Tracy .....	14	0
	<hr/>	
	204	10

\*Second Geol. Survey of Pennsylvania, Atlas, Southern Anthracite Field, Part IV, Sheet No. V.

## THE MICROSCOPIC STRUCTURE OF COALS OF THE MONONGAHELA SERIES\*

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The Monongahela series contains four workable coal beds—namely, from the bottom upward: the Pittsburgh, Redstone, Sewickley, and Waynesburg. On account of its inaccessibility and unimportance, the last named has not been studied and is not included in this paper. Of these beds, the Pittsburgh coal is of greatest importance and is probably the most important bed in the world. As far as known, there is no other bed of the same extent and average thickness. From the standpoint of nature, structure, and composition, it is also the most interesting, has been studied the most, and therefore most attention has been given it. In this paper the other two beds are considered more or less in comparison.

### Characteristics of the Pittsburgh Coal.

The Pittsburgh coal bed lies at the base of the Monongahela formation and rests on an uneven but persistent floor of fire clay which, in turn, rests upon an eroded surface of Conemaugh formation. The fire clay varies considerably in physical and chemical characteristics.

The Pittsburgh coal may be considered in two parts: the roof coal and the main coal. The former consists of a varying number (two to eight) of seams of varying thicknesses, usually termed "riders" or "roosters," from a fraction of an inch to about 8 feet in thickness. In the Experimental Mine of the U. S. Bureau of Mines at Bruceton, Pa., there are only two characteristic rooster seams, whereas in the Francis mine at Burgettstown, Pa., a varying number of seams are mined, from one to eight, differing in thickness from a few inches to 8 feet.

The main or worked bed is arbitrarily divided by miners into three parts: the breast coal on the top, the bearing-in coal near the middle, and the brick coal at the bottom. There are, however, no sharp dividing lines between these strata, and they may gradually merge into one another.

The breast coal at the top is the thickest and is considered the best part of the bed. As a rule, the bearing-in coal is supposed to be separated from the breast coal above and the brick coal below by shale partings, and is only between 4 and 6 inches in thickness. The shale partings, however, are not continuous and often overlap each other. The bearing-in coal breaks and shatters easily; it has been given the

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name because in the time of pick mining the miners started in on this portion to get a free face against which to bring out the other parts of the bed. The brick coal takes its name from the angular and sharp-cornered shapes the lumps tend to assume when mined. The bottom part of this coal is commonly called the floor coal, and is that portion left in the mine upon which the tracks are laid. It is rarely mined on account of its high ash content, including a large amount of pyrite.

#### Macrostructure of the Bed.

The entire bed is definitely banded into more or less well defined layers, as show in Plate I. If a lump of the coal is observed more closely it seems to be rather finely striated, as shown in Plate II. The Pittsburgh coal is more finely striated or laminated than most coals, the laminations being relatively thin. Numerous black shiny bands lying between duller ones, Show in Plates I and II as greyish bands, will be noticed in the coal. The shiny bands are constituents derived from definite woody parts of plants, parts that have retained some of their original identity and are called woody coal or "anthraxylon." These bands actually consist of sheets of coal, of greatly varying sizes and thickness within certain limits. The duller constituents in which the former may be said to be embedded are derived from all kinds of plant matter reduced to a finely macerated attrital matter. These are called the "attritus."

Frequently on splitting open a piece of coal a number of the smaller sheets of anthraxylon are exposed on the cleavage surface, as shown in Plate III.

The proportion of the woody constituent or anthraxylon to the attritus varies from place to place in the bed, but as a rule there is a larger proportion of anthraxylon at the bottom than at the top of the bed, so that as one proceeds from the bottom to the top the proportion of anthraxylon decreases whereas that of the attritus increases. This is shown in Plates IV, V, VI, VII, VIII, and IX, made from samples taken at about 12-inch intervals and magnified 10 times.

This phenomenon is interesting and may be observed in a number of coal beds. Its explanation may be that during the formation of the peat bed which eventually gave rise to the Pittsburgh coal, the area was subsiding. The swamp began in a mesophytic forest and the peat first formed was of a woody nature, so that the resultant coal contains a considerable portion of coal derived from woody matter. As time passed and the subsidence continued, the accumulation of peat could not keep pace with the rising water level and the swamp became increasingly hydrophytic. In consequence, the peat was more highly macerated and contained less and less woody matter and the result was an attrital coal.

## MINUTE STRUCTURE.

## The Anthraxylon.

The anthraxylon of a coal is that constituent derived from definite fragments of woody tissues, either of the xylem or the cortex of the ancient plants. During the peat stage of the coal all plant matter was subjected to a process of decomposition through the agency of fungi, actinomyces bacteria, burrowing insects, and other low forms of life. Wood is chiefly composed of cellulose and lignin, with which hemicellulose, oils, fats, and waxes are associated, as well as a few other substances in smaller amounts. During the processes of decay all substances except the lignin are almost completely or largely decomposed. The lignin sustained some loss, but most of it was transferred into humin, and out of this the coal was largely formed. During the peat-forming period some of the woody tissues remained as definite fragments in which the woody structure has been preserved, but they consist of little else than a derivative of lignin. These are the constituents in coal recognized as the black shiny layers and streaks, the anthraxylon, in which the woody structure has been more or less unchanged.

As observed, the anthraxylon sheets, represented by the black glistening strips in coal, are relatively thin, ranging from only a fraction of a millimeter to barely more than a centimeter, although occasionally there are thicker bands. Plate X, A, is a thin section with a number of these sheets of anthraxylon embedded in the attritus. All sheets or bands of anthraxylon when observed in thin sections under the microscope at a magnification exceeding 100 diameters show cell structure. In some this cell structure is remarkably well preserved; in others it is merely indicated by fine striae, with all possible degrees of preservation between these extremes. A fair idea of the relative thickness and distribution of this constituent has already been given in Plates IV to IX, inclusive.

Two characteristic types of woody structure are to be observed, and most of the structures observed are of these types. That most prevalent is shown in Plate X, B. The woody fibers appear much compressed and give the section a smooth, striated appearance under the microscope. This structure is common throughout the coal and is responsible for its characteristic appearance.

This characteristic structure has a number of transition forms; in other words, a number of variations exist, probably due to different stages of preservation. With this is frequently associated a delicate structure as shown in Plate XI, sometimes resembling growing points of branch tips; it is possible that it belongs to the same plant that gave rise to the striated structure in the coal.

The other common structure is shown in Plate XII. This is commonly found in the thicker anthraxylon bands. It also varies and has

transition forms. This illustration shows that the cell lumina are filled more or less with a resinous-appearing inclusion which probably was the cause of its good state of preservation.

The anthraxylon may occur in exceedingly thin sheets, often with but a vague plant structure only recognizable as such by an experienced observer (Plate XIII). These are often closely packed and give the appearance of a solid anthraxylon, whereas actually there are a number of closely piled units one on top of the other. Although in a cross section the plant structure may be vague and indefinite, when a horizontal section is prepared the cell structures are clearly shown, leaving no doubt as to their woody origin.

The explanation of the numerous thin anthraxylon sheets in the Pittsburgh coal may possibly be found in the nature of the plants contributing to the coal. The nature of the woody stems may have been such that during the process of decay they were easily delaminated into thin sheets. There are examples of this peculiarity in a number of living species of trees, the best being the American basswood. The basswood stems, in a semi-rotted condition, may be peeled off sheet after sheet in thin paper-like laminae. However, in stems well rotted such sheets will easily break up into small patches. Judging from the small woody fragments seen on the horizontal cleavage surfaces, such delamination and breaking up into smaller patches may well have happened; in fact, many of the woody fragments in peat are of this nature.

#### The Attritus.

As already noted, the attritus at a low magnification is of a granular striated appearance, giving little information as to its composition (Plates IV to IX). At a higher magnification it is at once resolved into a number of interesting constituents and the following may be distinguished: Small bits of anthraxylon or woody degradation matter, degradation matter of related carbohydrate substances, resinous matters, spores, pollins, cuticles, and opaque matter. A brief account of these follows:

**Woody degradation matter.** As a rule, woody degradation matter constitutes the larger part of the attritus. It has the same general appearance, such as color, is of the same physical nature as the anthraxylon, and like it derived largely from the lignin of plants; it is therefore of the same composition except that it is more highly comminuted (Plate XIV). Besides the woody degradation matter there is always a considerable amount of matter derived from bark, cortex, pith, leaf-tissues, etc., which is similar in appearance to the woody degradation matter. Another constituent, shown in Plate XV, is characteristic in the Pittsburgh coal. Its origin is not definitely known, but it resembles bark tissues.

**Spores.** The spore matter in the attritus is of greatest interest. Spores are ever present and all-pervading; no section has yet been cut

that did not contain many of them. A most remarkable fact is that most of them are of one and the same kind. There are a number of other spores present, but they form only a small part of the total spore matter. Plate XVI, A, shows the form of this spore in cross section. It will be noticed that the surfaces are finely corrugated. Plate XVI, B, shows the appearance in a horizontal section. It is here shown that the corrugations seen in the cross section are due to delicate ridges on the surface. This spore is relatively small, only about 13 to 15 microns across the disc.

These spores are distributed through the entire Pittsburgh bed from one end to the other and from top to bottom. The bed contains, in general, in direct proportion with attritus, increasingly larger numbers of spores toward the roof; but the distribution is not uniform; some layers are composed predominately of spores; other layers contain relatively few.

Another remarkable fact is that this particular spore has not yet been found in any other bed. Therefore, as it is found only in the Pittsburgh bed it affords an easy and safe method of identifying the coal, except perhaps in areas where the coal is too highly metamorphosed.

In addition to this predominating spore, there are a few other types. One of these, a megaspore, shown in Plate XVII, A and B, may be mentioned. In one cross section it reveals the same kind of a saw edge as the predominating microspore, but the surfaces are adorned with delicate ridges. It seems possible that this megaspore is the mate to the microspore in the same heterosporous plant. A large smooth microspore or small megaspore is prominent in certain places in the lower part of the bed (Plate XVIII, A).

Pollens are also disseminated through this coal, but in much smaller numbers. Like the spores they are compressed and flattened and are shown as oval or ovoid discs, with a cross-like slit on one side. They are always smooth.

#### Fusain or Mineral Charcoal.

There is a good deal to be said regarding fusain, but it is impossible to give the amount of space and time it is usually accorded. A cross section (Plate XVIII, B) shows its definite and well-preserved cell structure. As a rule the structure is that of wood.

**Opaque matter.** The attritus of all coals always contains a group of components in the form of rather small irregular particles of an opaque nature, and for want of a better name they are referred to as "opaque matter." This matter is found throughout the Pittsburgh bed, and in some layers it is concentrated in considerable quantities and determines the nature of the coal. Such a section from the Pittsburgh coal is shown in Plate XIX. In sections of ordinary thickness the opaque

matter when crowded together appears quite opaque and presents a homogeneous background. In very thin sections the opaque matter becomes more or less translucent. The section is then shown to be very heterogeneous and to be composed of particles of varying shapes, densities, and color. As a rule, the opaque matter is accompanied by numerous spores, but not necessarily so.

In some coals, particularly in certain definite seams, the opaque matter forms the larger part, and then lends specific and definite characteristics to the coal. In America, such coals are called "splint coals," as in the Hershaw bed of West Virginia, the High Splint and the Harlem beds of Kentucky. In England such coals are called "durain" and in Germany "Mattkohle."

#### Other Structure.

In the study of coal there are a number of other interesting structures. One shown in Plate XX, A, is repeatedly observed. Obviously, it is derived from a delicate tissue of the nature of a prothallium. Another structure which is occasionally seen is shown in Plate XX, B. As can clearly be discerned, it is a megasporangium enclosing spores.

#### CHARACTERISTICS OF THE REDSTONE COAL.

The Redstone bed lies 40 to 80 feet above the Pittsburgh bed. It is overlain by sandstone 60 to 70 feet in thickness, making an ideal roof for mining. It rests on a soft fire clay, which necessitates leaving a rather thick layer of coal for a floor.

The geology of these coals was the subject of other papers in this symposium and need not be further dwelt upon in this one. In comparison with the Pittsburgh coal, the Redstone lacks the bright clean appearance so characteristic of the former as seen under the microscope. It contains considerable quantities of finely divided and fairly generally disseminated kaolin, quartz, and sericitic mica from the decomposition of feldspar. Plate XXI is a section at high magnification containing a large portion of this mineral.

The coal also contains considerable quantities of finely divided pyrite. Sections as shown in Plate XXII, Sewickley coal, are common. The Redstone coal as a whole is more anthraxylous than the Pittsburgh coal, and like the latter is more so at the bottom than toward the top; it becomes more and more attrital toward the roof, thus changing from a highly anthraxylous coal at the bottom to a highly attrital coal at the top, as shown in the illustrations.

Plate XXIII is a representative section toward the floor, Plate XXIV near the middle, and Plate XXV near the top.

The cell structures in the anthraxylon throughout the coal bed is poorly preserved. In cross section it is recognizable only as fine striae; in horizontal sections, however, it is revealed distinctly.

### The Attritus.

The attritus of the Redstone coal is largely composed of humic degradation matter and contains relatively few spores, resinous matter, and opaque matter.

**Spores.** The spore content of this coal is much lower than that of the Pittsburgh coal; it is particularly low in the lower horizon and becomes somewhat more abundant toward the roof; here and there are zones that contain large numbers, as shown in Plate XXVI, but such sections are rare. The microspores are, as a rule, poorly preserved and are of little use for identification purposes.

The Redstone coal contains three characteristic megaspores: The most prominent is shown in Plate XXIII and Plate XXVII, A. It is a megaspore of variable size, reaching a maximum diameter of 2,000 microns. Its shape is rather peculiar, being lenticular and tapering off into fine edges, and often folded upon itself, as shown. This spore is composed of two layers. The outer layer is of a light yellow color and granular; the inner layer is thinner, of a brownish color, and less granular. The granular nature is its most characteristic feature.

A second characteristic spore is shown at a higher magnification in Plate XXVII, B, and at a lower magnification embedded in the attritus in Plate XXV. This spore has a more regular shape, is thick-walled, and 70 to 90 microns in diameter; therefore it must be classed among the megaspores. It is rarely found in the lower strata, but it is fairly numerous in the upper layers.

A horizontal section of a third characteristic spore, at a lower magnification, is shown in Plate XXVIII, and at a higher magnification in Plate XXIX, A and B. This is also a megaspore. It is larger than the spores previously shown and its surface is profusely sculptured, giving it a saw-edge appearance in cross section.

In addition to these three spores there are a number of other non-descript spores without definite characteristics.

### CHARACTERISTICS OF THE SEWICKLEY COAL.

Like the Redstone coal, the Sewickley coal contains much mineral matter which is reflected in the appearance of the coal under the microscope. It contains in the first place, wherever found, a number of clay partings which add considerably to the ash content. Again, like the Redstone coal, the Sewickley coal contains considerable quantities of kaolin and sericitic mica, which are persistent throughout the bed. Finely disseminated pyrite is also persistent. Sections as shown in Plate XXII are common. The dark irregular spots represent the pyrite globules which, in turn, are aggregates of innumerable tiny pyrite cubes.

Like the Redstone coal the Sewickley coal is highly anthraxylous, although somewhat less so than the former. Like the Redstone, it is more anthraxylous at the bottom than at the top, and proceeding from



PLATE I.—Cross section of the Pittsburgh coal bed in the experimental mine of the U. S. Bureau of Mines at Bruceton, Pa. The section of the bed shown is approximately 7 feet in thickness. Much reduced.

the bottom to the top the proportion of anthraxylon to attritus changes from a preponderance of anthraxylon to a preponderance of attritus, so that toward the roof the coal is highly attrital.

In thin section under the microscope the coal resembles the Redstone coal in many ways, but it is not as closely packed. Structure in the anthraxylon is poorly preserved, and the little that may be observed resembles that in the Redstone coal. Plates XXX, XXXI, and XXXII are typical examples; no definite cell structure is revealed. The fine striations are traces of such structure and in horizontal sections are distinctly shown to be the remains of woody structures. Resinous inclusions, as a rule are not abundant, but here they are fairly prominent, as shown in Plate XXXII.



PLATE II.—A block of Pittsburgh coal taken from the upper part of the bed showing the layering of the coal as seen on a vertical cleavage plain. The dark bands represent the anthraxylon sheets, embedded in the attritus, shown in gray. Natural size

### The Attritus.

The attritus of the Sewickley coal is composed largely of humic matter, containing, as a rule, relatively few spores and little opaque matter. The spores are not well preserved, so that the microspores are identified with some difficulty.

**Spores.** The most characteristic spore in the Sewickley coal is a small crinkled one somewhat resembling the Pittsburgh spore, as may be seen in Plate XXXIII, A and B. On close examination it is found to differ enough to be clearly distinguishable from the Pittsburgh spore. It is larger, measuring approximately 18 to 20 by 20 to 25 microns across the disc. The sculpturings consist of coarse broad and blunt echinate humps, and not of serpentine ridges as in the Pittsburgh spore, and the crests are higher and farther apart. There are relatively few of these spores compared with the number of those in the Pittsburgh coal. There are three other spores in the Sewickley coal, either similar or identical to those of the Redstone coal.



PLATE III.—A block of Pittsburgh coal taken from the upper part of the bed, showing small patches of anthraxylon on the horizontal cleavage plane. Natural size.

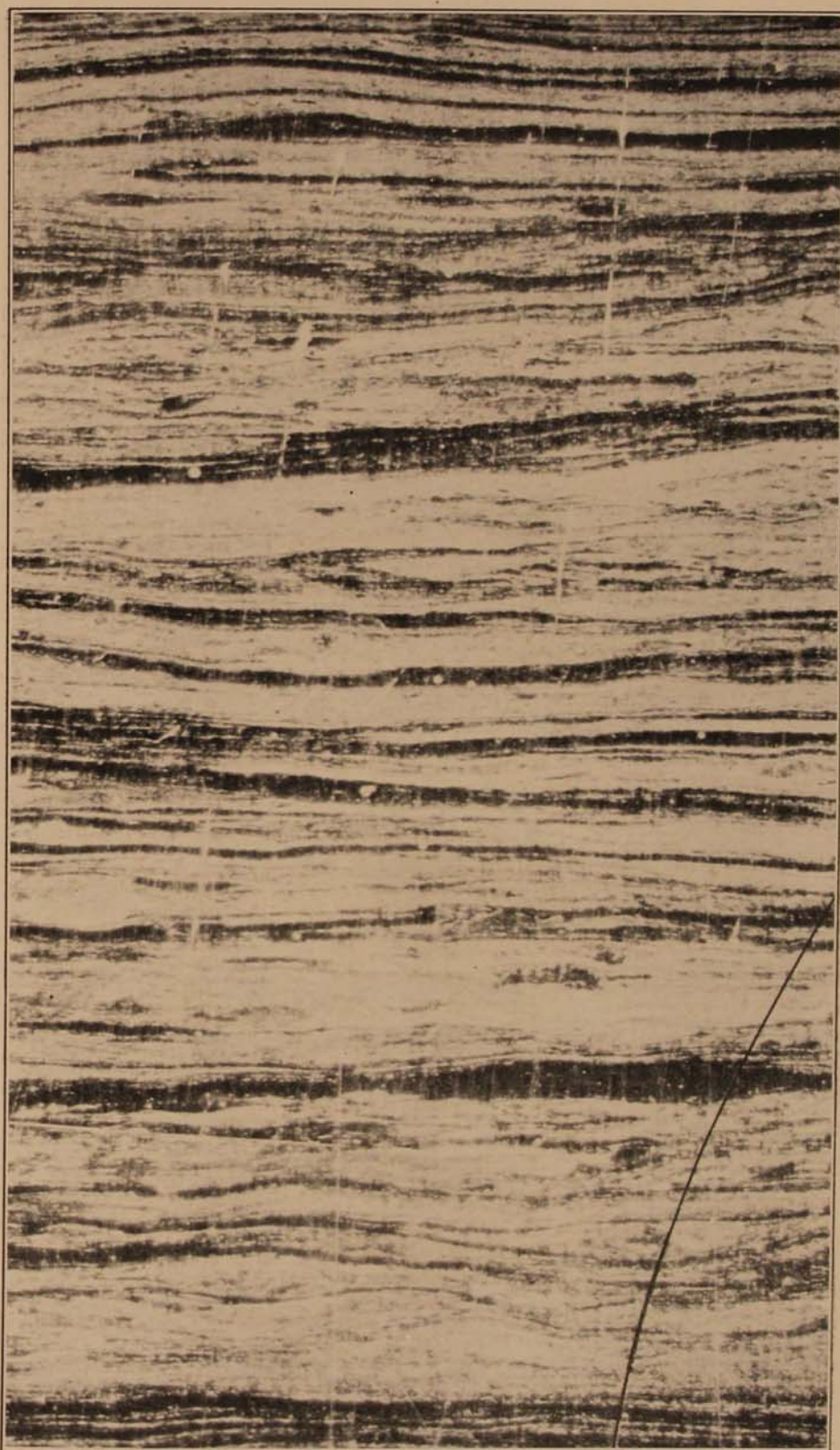


PLATE IV.—Plates IV to IX are vertical sections, prepared from polished vertical sections, by means of vertical illumination, at magnification of 10 diameters, from samples taken at about one foot intervals consecutively from the floor to the roof, to show the gradual decrease in anthraxylon and increase in attritus and their relative amounts of each step. Anthraxylon shown as black bands and hair-like streaks; attritus in gray. 10X.

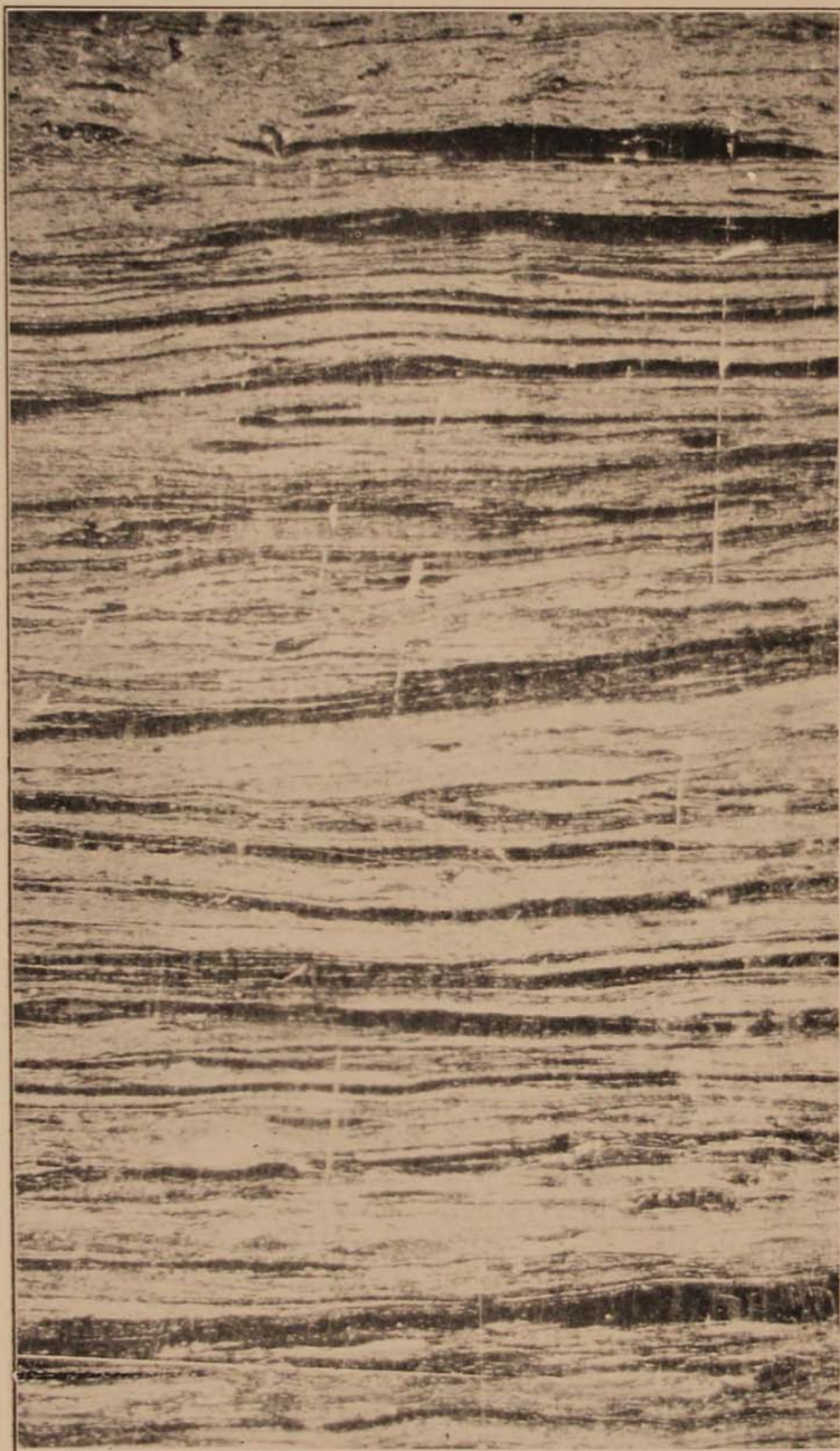


PLATE V.—Plates IV to IX are vertical sections, prepared from polished vertical sections, by means of vertical illumination, at a magnification of 10 diameters, from samples taken at about one foot intervals consecutively from the floor to the roof, to show the gradual decrease in anthraxylon and increase in attritus and their relative amounts of each step. Anthraxylon shown as black bands and hair-like streaks; attritus in gray. 10X.



PLATE VI.—Plates IV to IX are vertical sections, prepared from polished vertical sections, by means of vertical illumination, at a magnification of 10 diameters, from samples taken at about one foot intervals consecutively from the floor to the roof, to show the gradual decrease in anthraxylon and increase in attritus and their relative amounts of each step. Anthraxylon shown as black bands and hair-like streaks; attritus in gray. 10X.

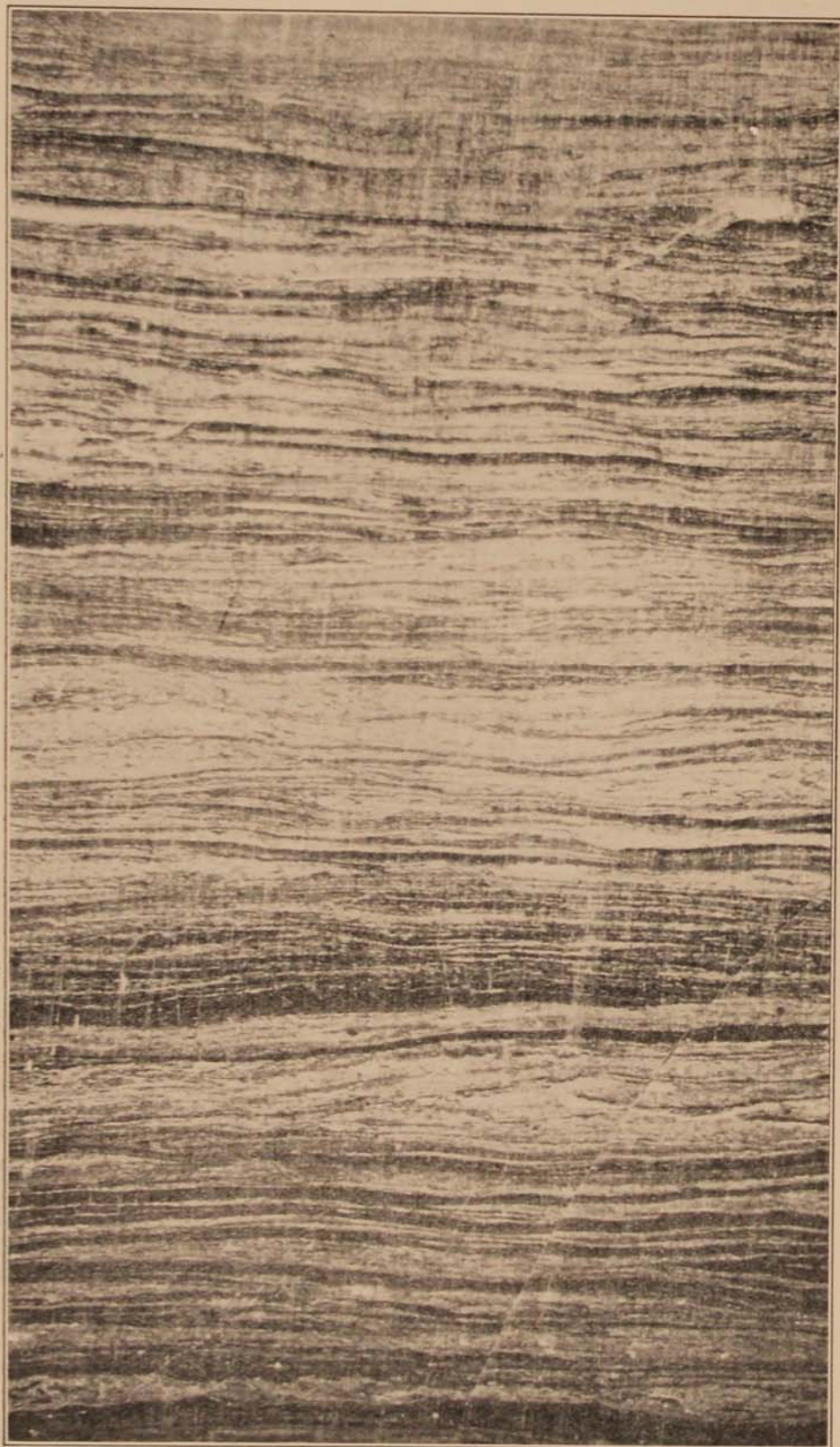


PLATE VII.—Plates IV to IX are vertical sections, prepared from polished vertical sections, by means of vertical illumination, at magnification of 10 diameters, from samples taken at about one foot intervals consecutively from the floor to the roof, to show the gradual decrease in anthraxylon and increase in attritus and their relative amounts of each step. Anthraxylon shown as black bands and hair-like streaks; attritus in gray. 10X.

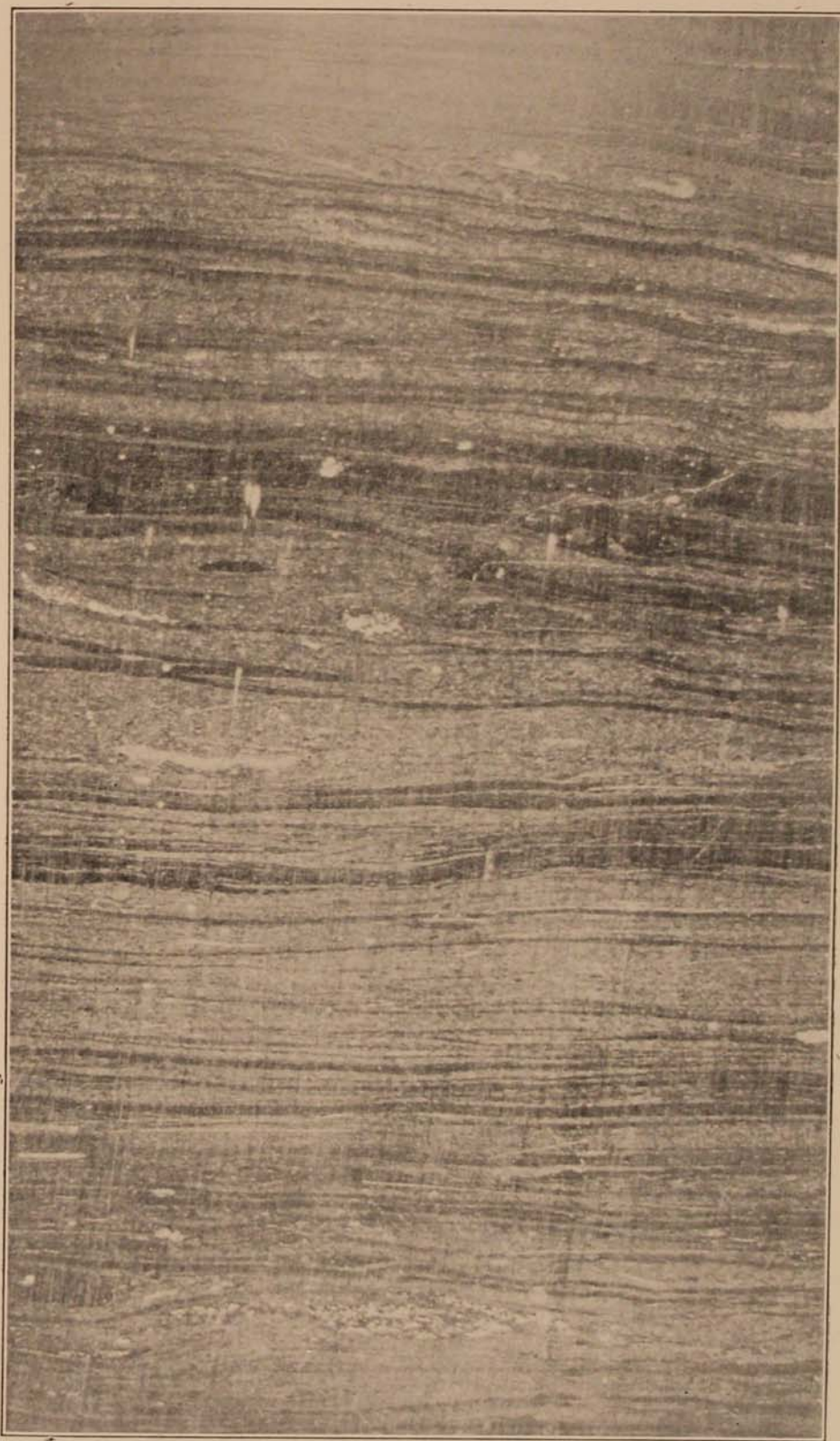


PLATE VIII.—Plates IV to IX are vertical sections, prepared from polished vertical sections, by means of vertical illumination, at a magnification of 10 diameters, from samples taken at about one foot intervals consecutively from the floor to the roof, to show the gradual decrease in anthraxylon and increase in attritus and their relative amounts of each step. Anthraxylon shown as black bands and hair-like streaks; attritus in gray. 10X.

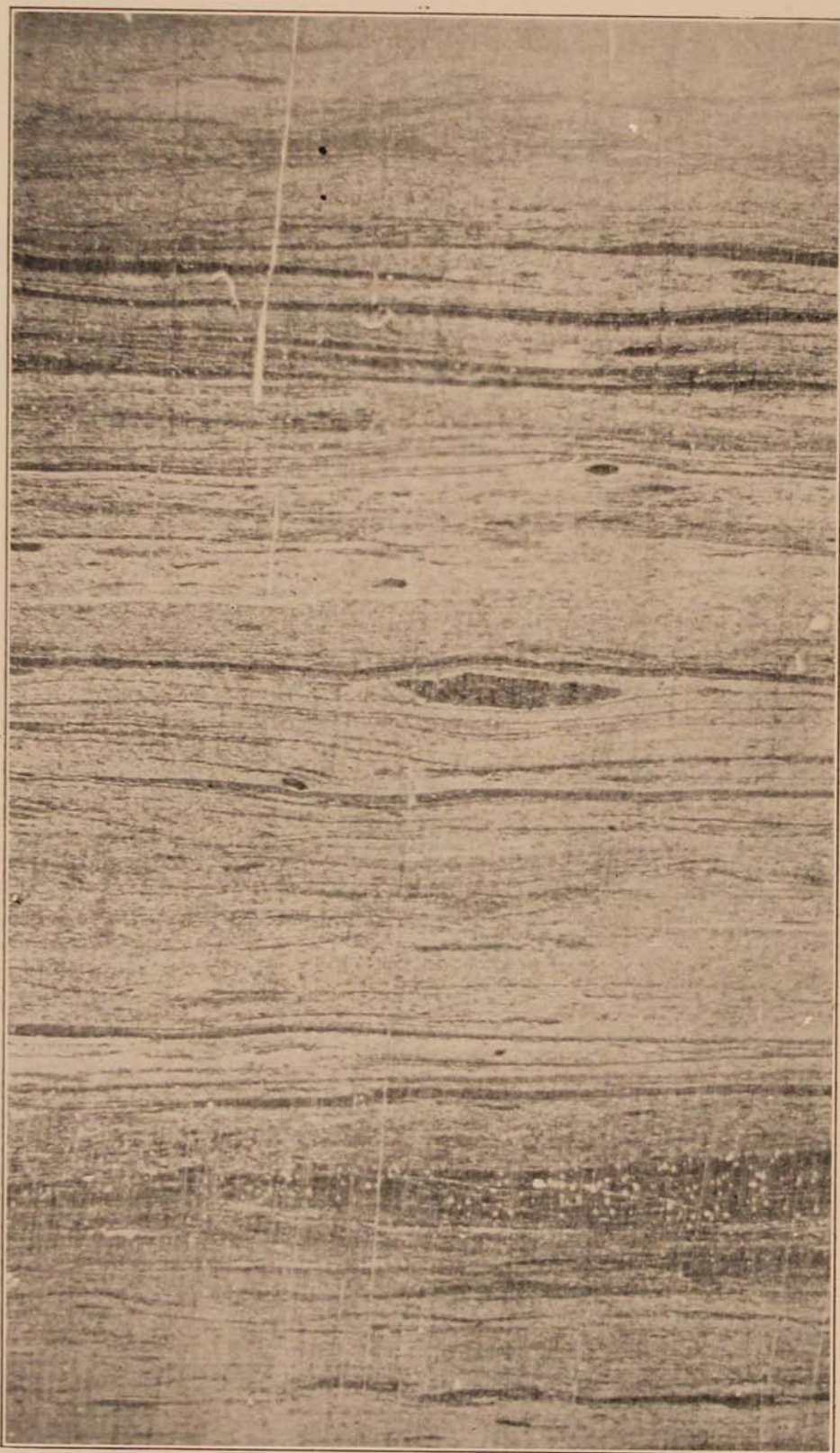


PLATE IX.—Plates IV to IX are vertical sections, prepared from polished vertical sections, by means of vertical illumination, at a magnification of 10 diameters, from samples taken at about one foot intervals consecutively from floor to roof, to show the gradual decrease in anthraxylon and increase in attritus and their relative amounts of each step. Anthraxylon shown as black bands and hair-like streaks; attritus in gray. 10X.

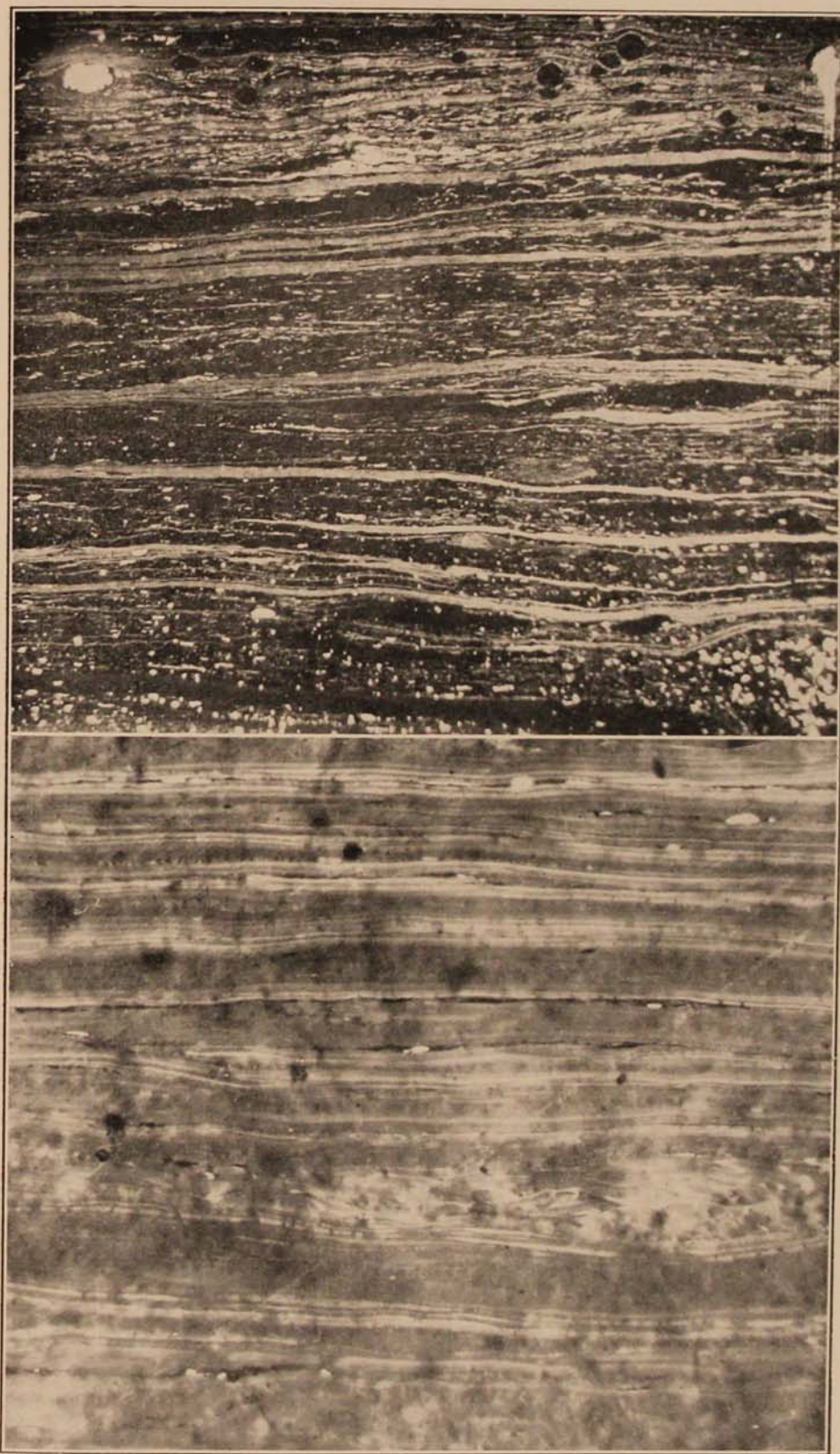


PLATE X, A.—Thin section of Pittsburgh coal from the upper part of the bed, taken by transmitted light, to show the appearance and relative amounts of anthraxylon in gray and attritus in dark at low magnification. X10.

PLATE X, B.—Thin section of a predominant type of anthraxylon in the Pittsburgh coal. X200.



PLATE XI.—Thin section of Pittsburgh coal showing delicate plant structure associated with the predominant type shown in Plate X, B.

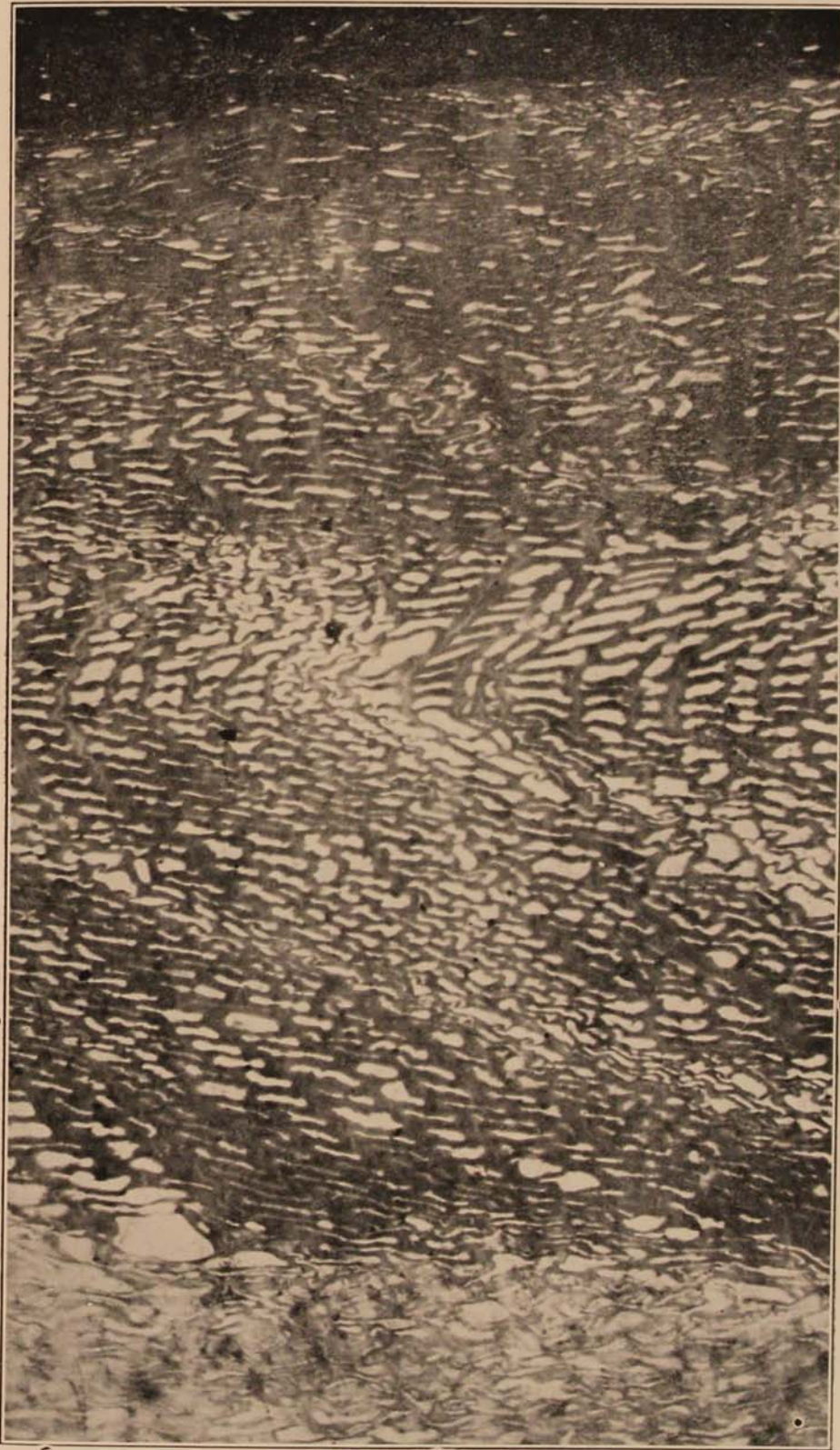


PLATE XII.—Thin section of anthraxylon of Pittsburgh coal with well preserved structure of a common type, with resinous contents. X200.



PLATE XIII.—Thin section of Pittsburgh coal with a number of thin anthraxylon strips in which the remaining plant structure is merely indicated by delicate striae. The attritus contains, besides the spores, some resinous particles and opaque matter.

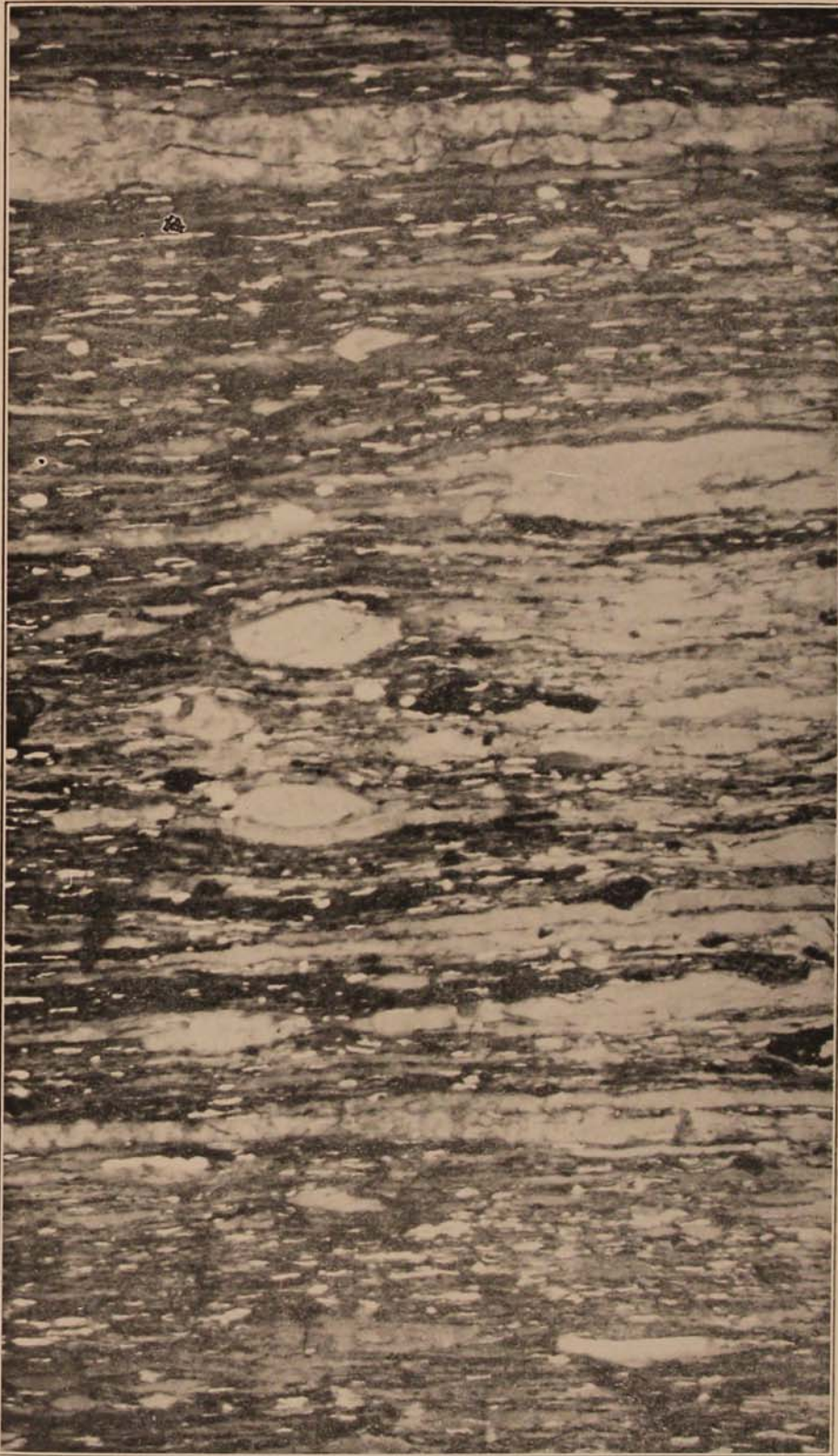


PLATE XIV.—Thin section of Pittsburgh coal representing an attritus rich in woody and humic degradation matter, with relatively few spores and some opaque matter.



PLATE XV.—Thin section of Pittsburgh coal showing a bark-like structure common in the coal. X200.

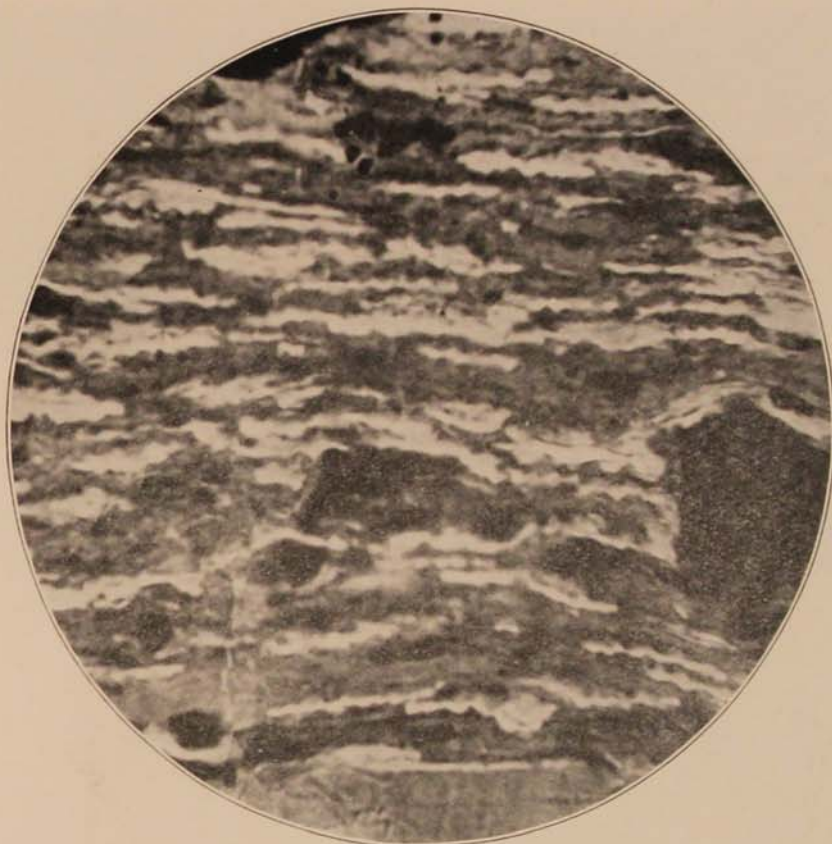


PLATE XVI, A.—Thin section of Pittsburgh coal at a high magnification, showing the Pittsburgh microspore in cross section. X1000.

PLATE XVI, B.—Pittsburgh coal in horizontal section showing the flat side of the Pittsburgh microspore. X1000.



PLATE XVII, A.—The Pittsburgh megaspore in horizontal section. X1000.  
PLATE XVII, B.—The Pittsburgh megaspore in cross section. X1000.

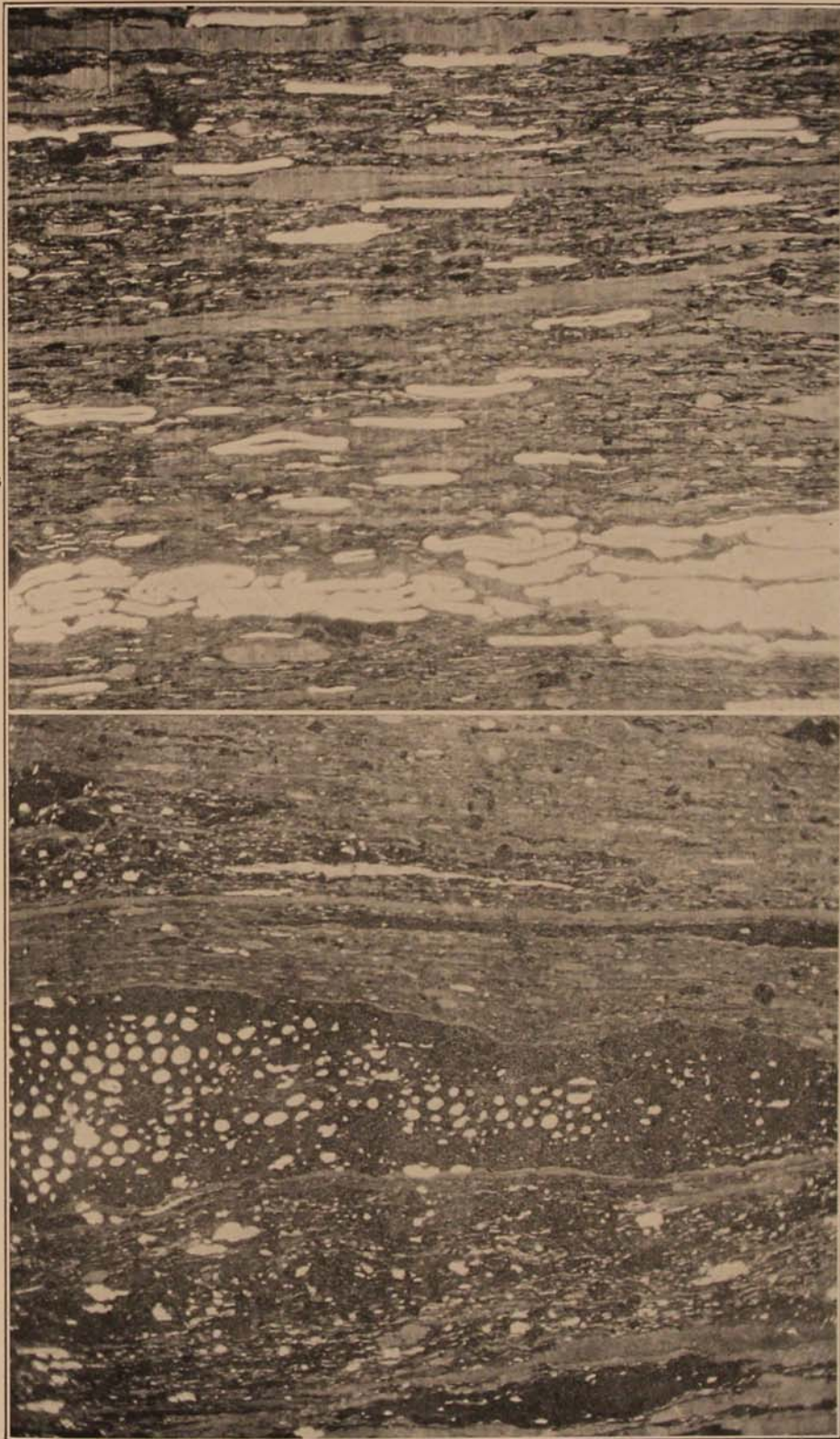


PLATE XVIII, A.—Thin cross section of attritus of Pittsburgh coal, showing a number of large smooth spores, with relatively few Pittsburgh microspheres. Notice the relative sizes of the two kinds of spores. X200.

PLATE XVIII, B.—Thin cross section of attritus of Pittsburgh coal including a parcel of fusain or mineral charcoal. The attritus contains besides the spores and humic degradation matter a considerable amount of opaque matter. X200.



PLATE XIX.—Thin cross section of attritus of Pittsburgh coal containing a large amount of opaque matter. Spores are shown in white; humic matter in gray and opaque matter in black. X200.



PLATE XX, A.—Thin horizontal section of Pittsburgh coal showing a structure resembling growing points of prothallia. X200.

PLATE XX, B.—Thin cross section of Pittsburgh coal including part of a megasporangium enclosing spores. X200.

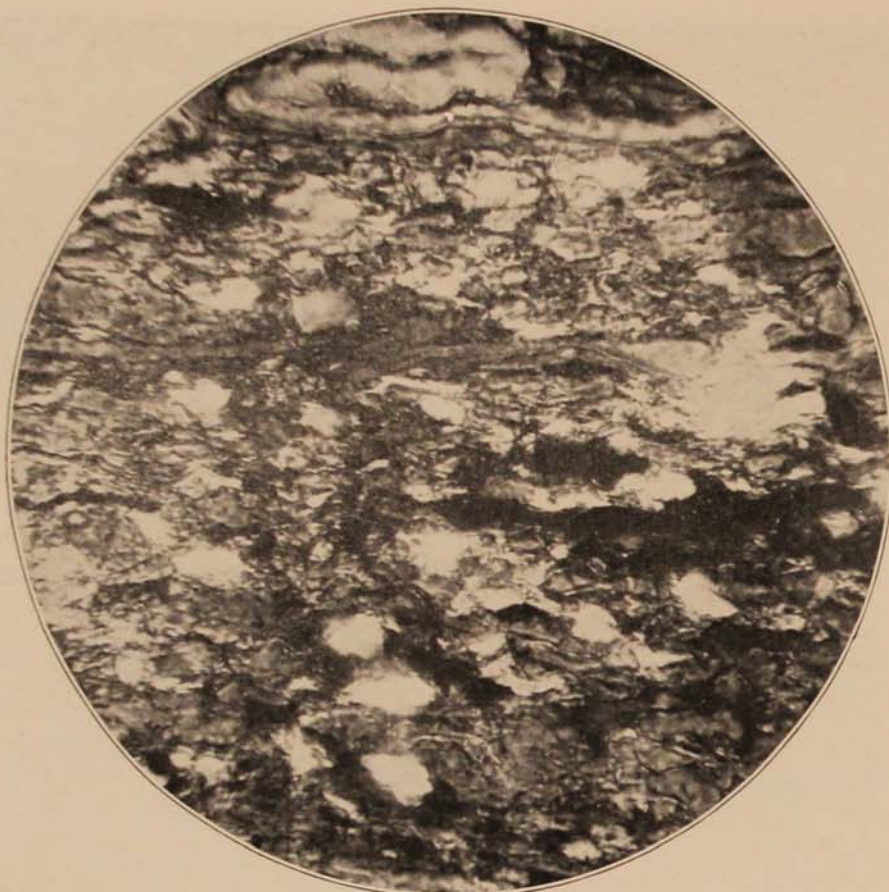


PLATE XXI.—Thin cross section of Redstone coal showing numerous particles of sericitic mica. X1000.

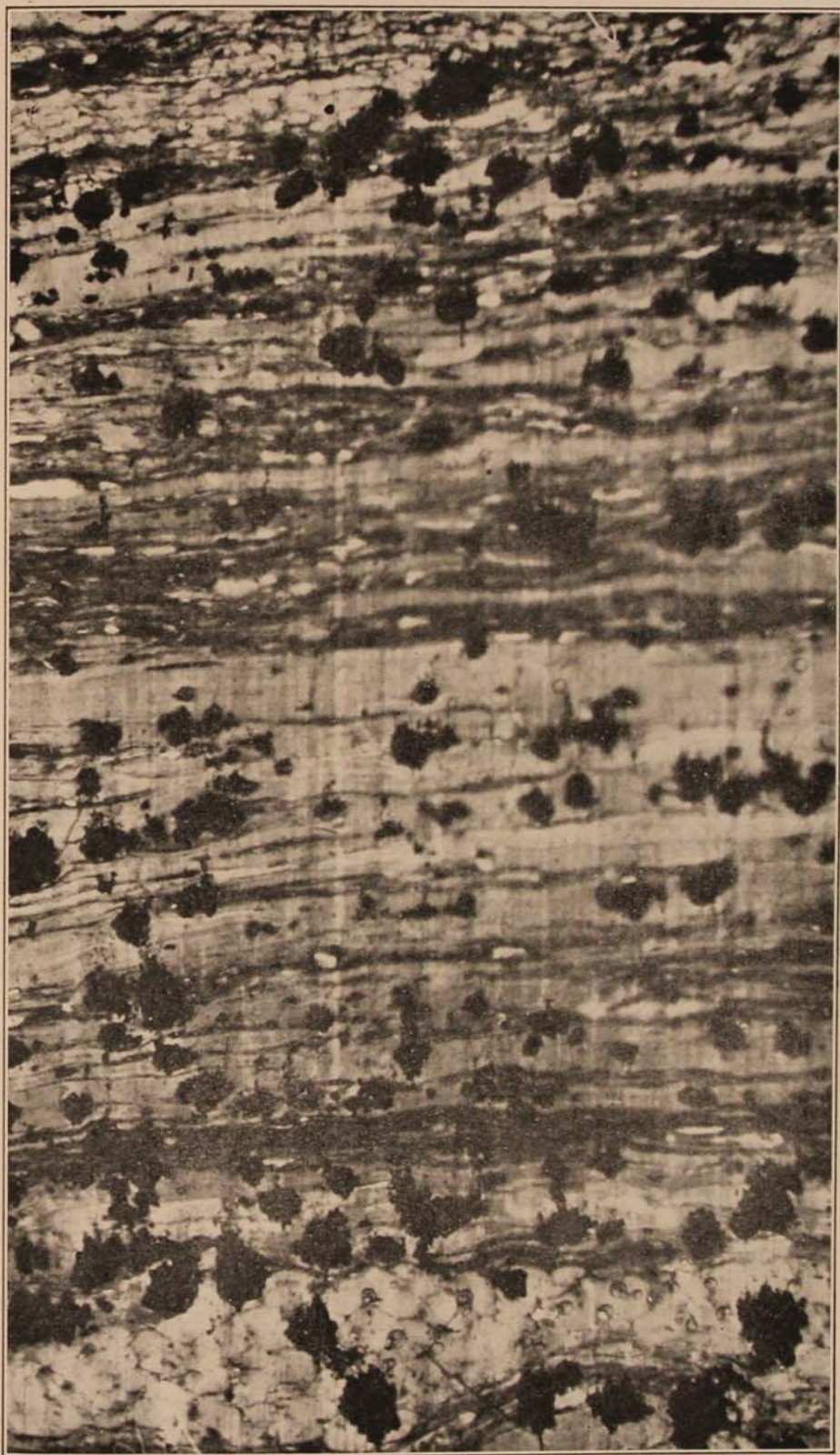


PLATE XXII.—Thin cross section of Sewickley coal, including numerous pyrite granules. Redstone coal is similar to this. X200.

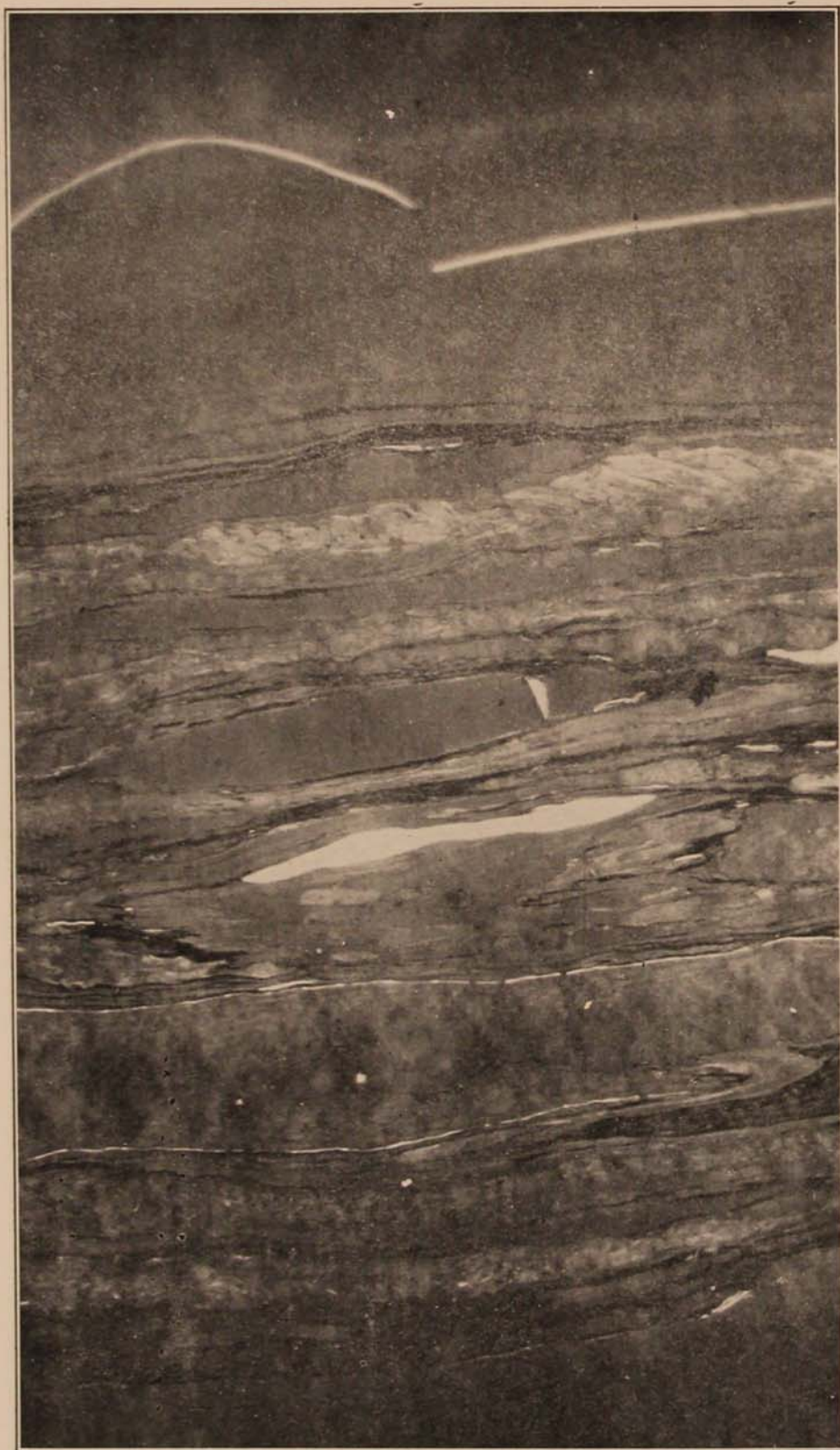


PLATE XXIII.—Thin cross section of Redstone coal showing the anthraxylous nature of the coal in the lower strata. A redstone megaspore is shown in the center. X200.

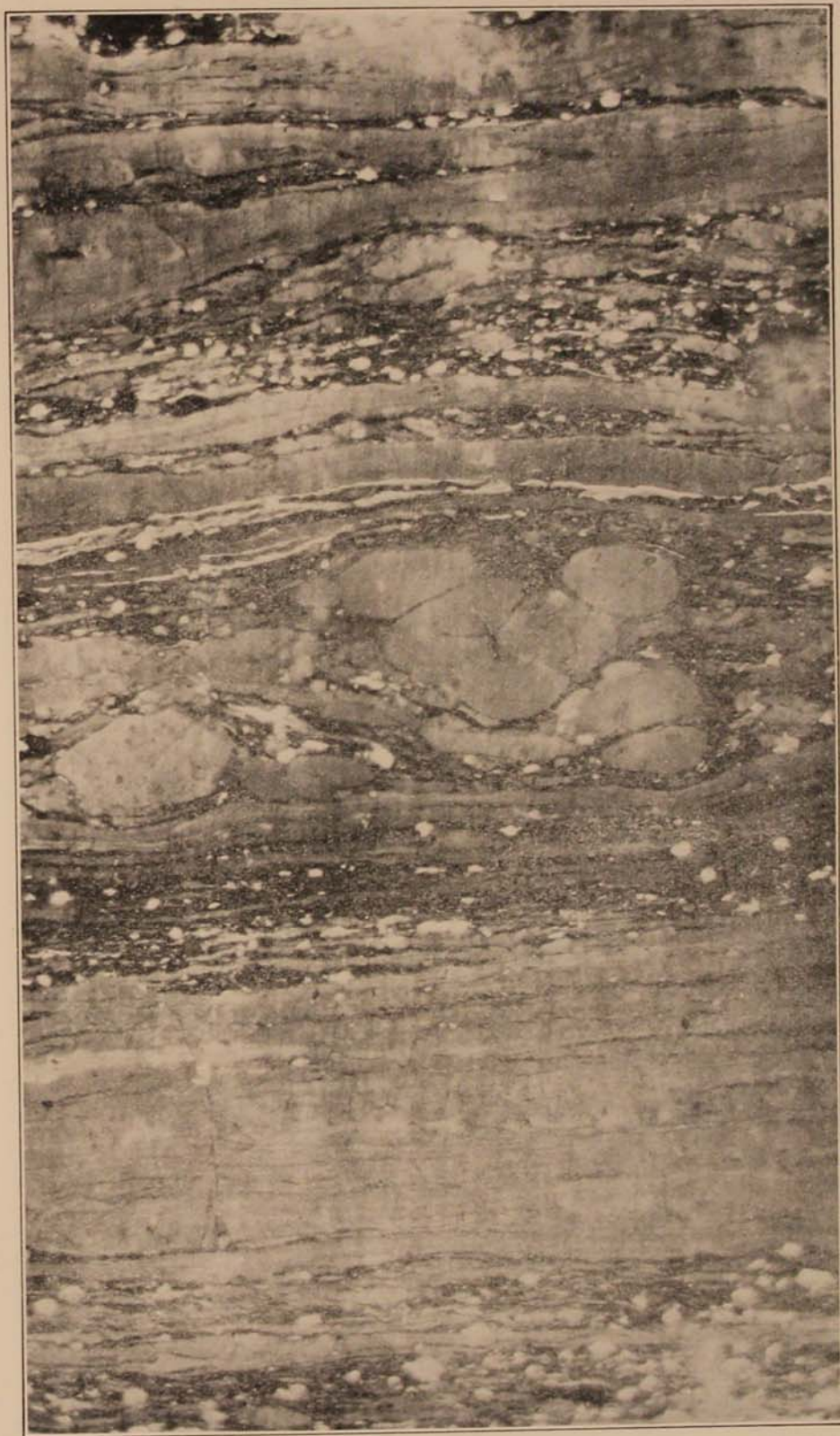


PLATE XXIV.—Thin cross section of Redstone coal from the middle strata of the bed. The plant structure in the anthraxylon is represented merely by fine horizontal striae. The attritus between the anthraxylon strips contains very few spores, some sericitic mica and some opaque matter. In the center are shown large resin particles. X200.



PLATE XXV.—Thin cross section of Redstone coal from the top of the bed. The coal here is composed largely of attritus. It will be noticed that a considerable number of spores are present. The larger of these are the small Redstone megaspores shown in Plate XXVII, A. X200.

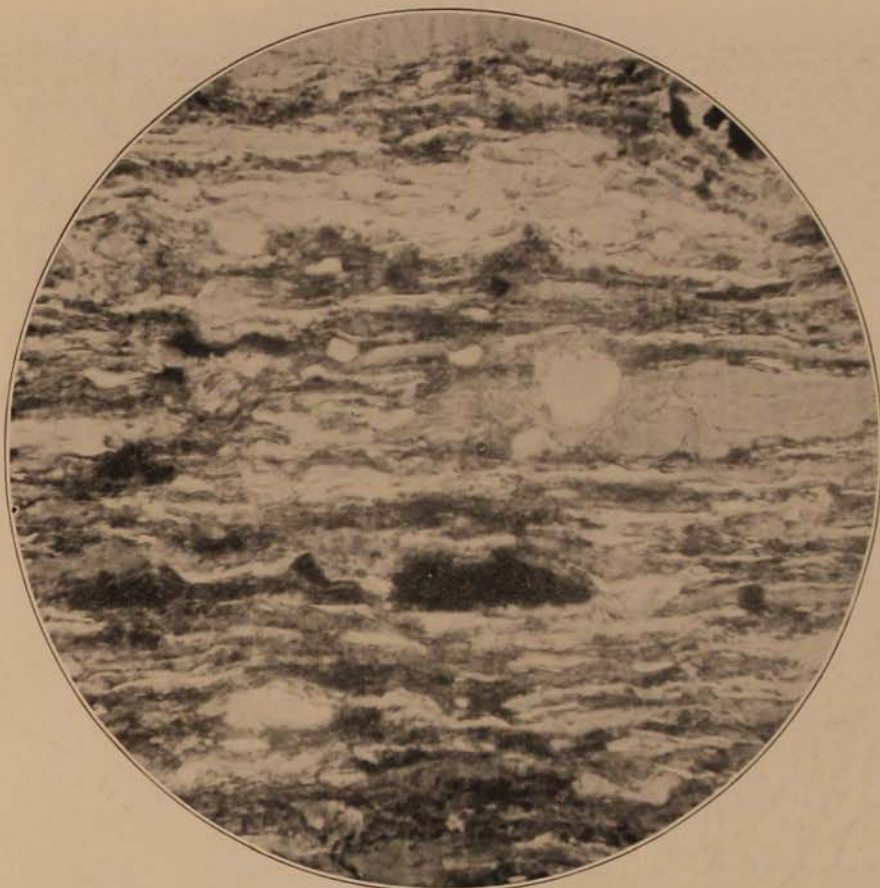


PLATE XXVI.—Thin cross section of Redstone coal showing an attritus with numerous microspores. These are poorly preserved and of indefinite outline. X1000.

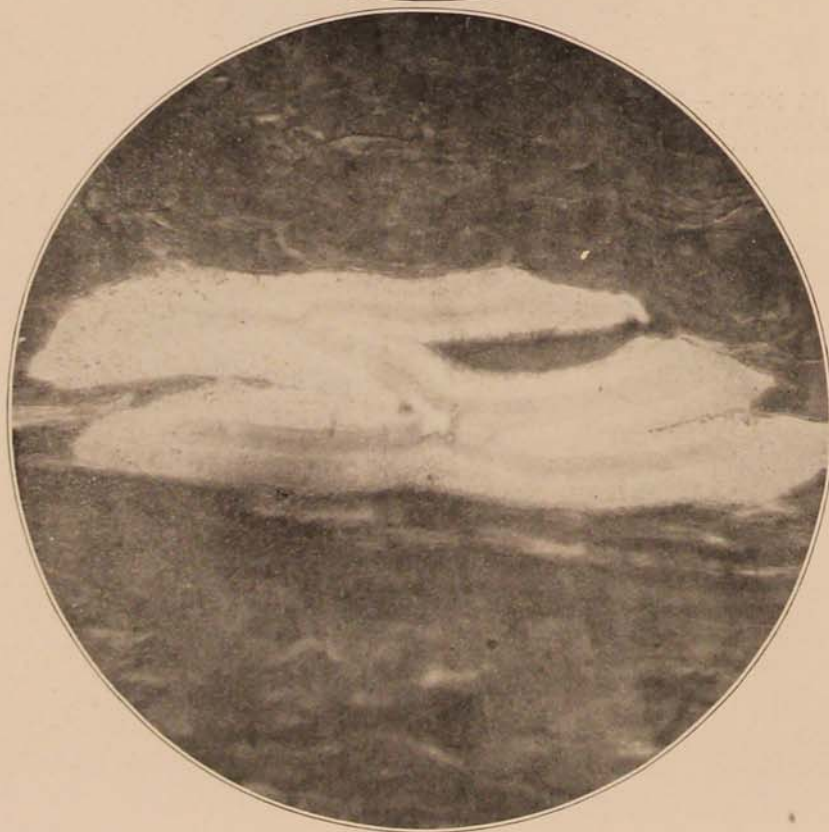
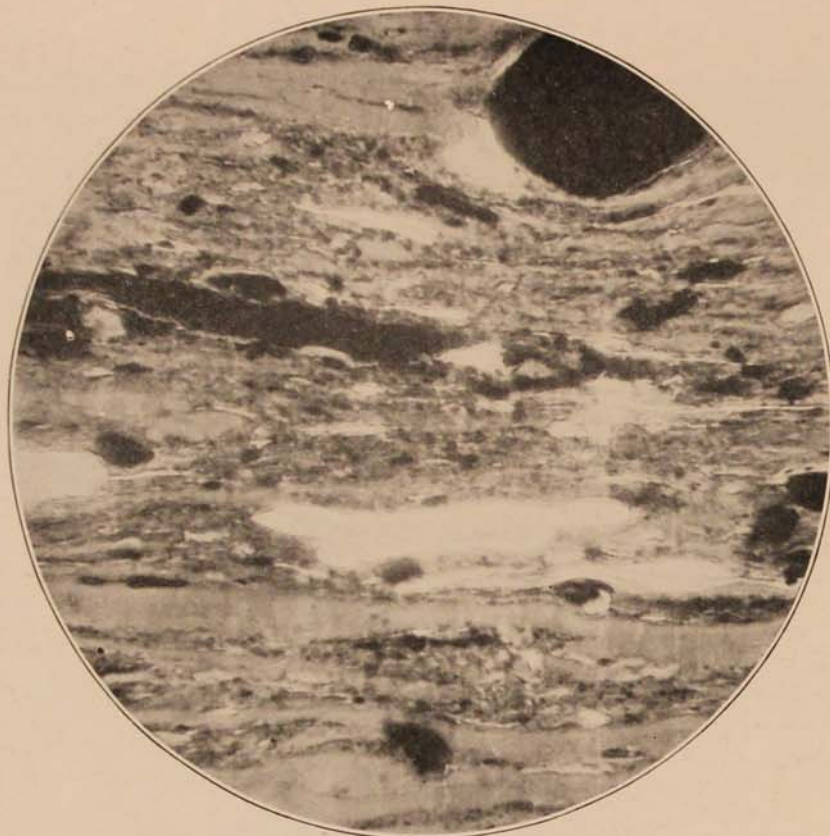


PLATE XXVII, A.—A thin cross section of Redstone coal showing the Redstone double-coated megaspores also shown in Plate XXIII at lower magnification. X1000.

PLATE XXVII, B.—Thin cross section of Redstone coal at a high magnification showing attritus including a characteristic Redstone spore, also shown in Plate XXV at a lower magnification. X1000.



PLATE XXVIII.—Thin horizontal section of attritus of Redstone coal including a number of sculptured megaspores, shown more highly magnified in Plate XXIX. X200.

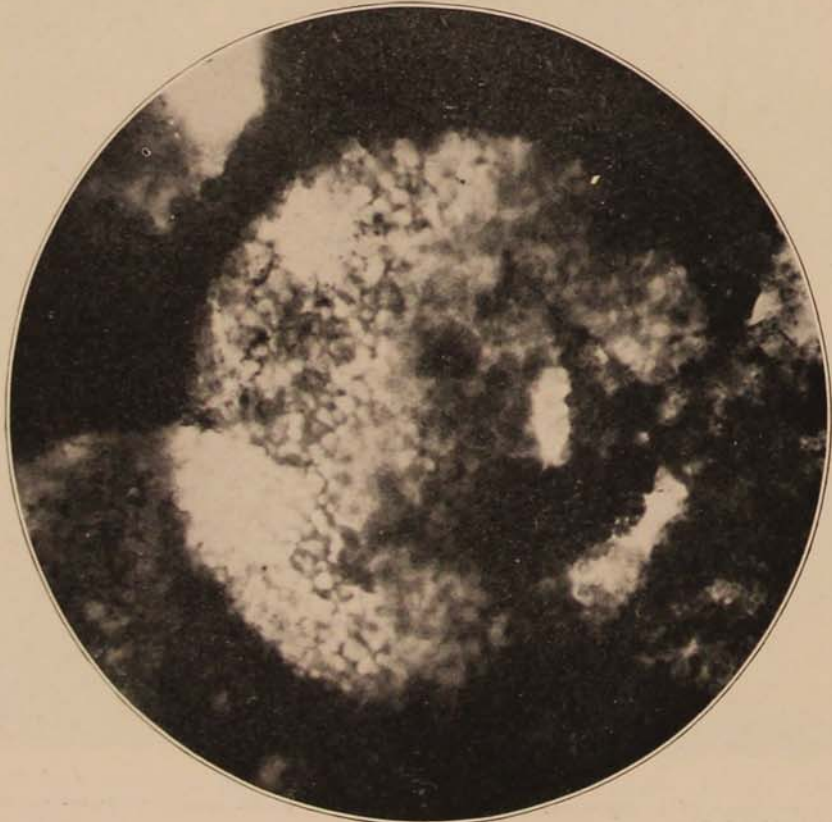
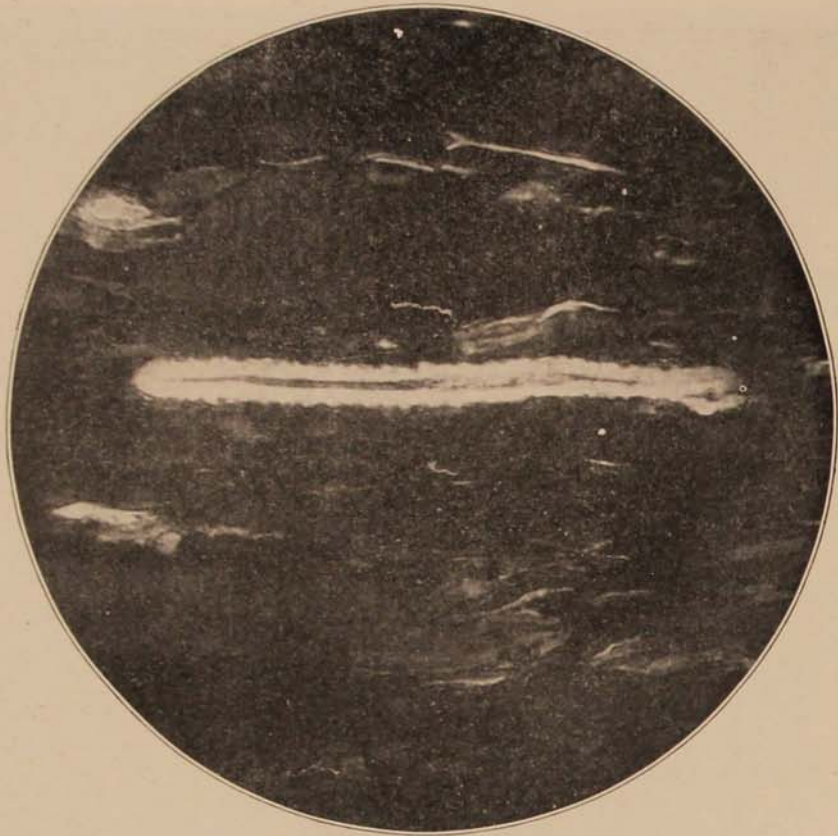


PLATE XXIX, A.—Thin cross section of Redstone coal showing the sculptured spore is seen in Plate XXVIII at a higher magnification. X1000.  
PLATE XXIX, B.—Horizontal section of Redstone coal showing the same spore in horizontal section at the same magnification. X1000.

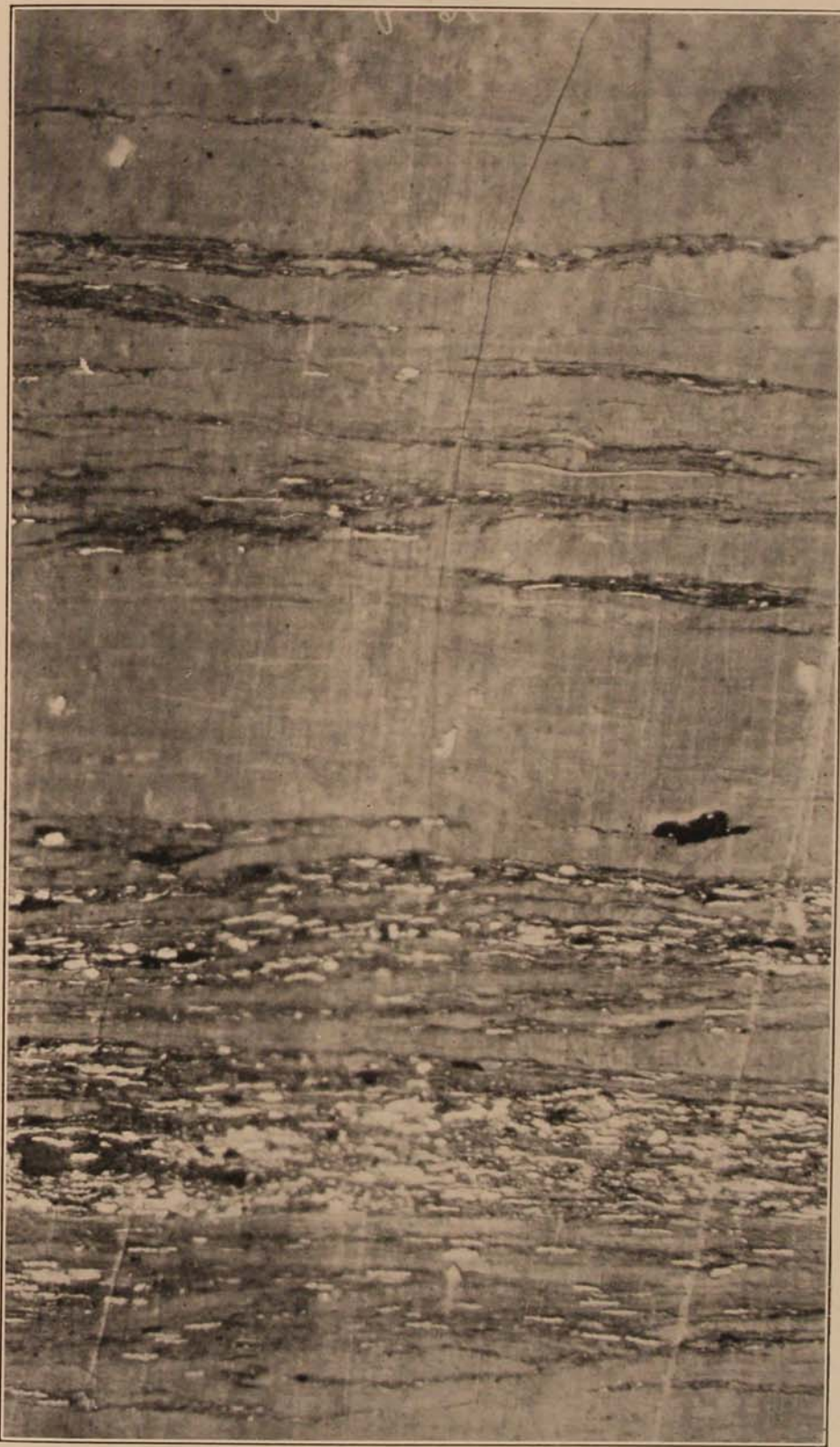


PLATE XXX.—Thin cross section of Sewickley coal showing the general nature of the Sewickley coal near the floor.



PLATE XXXI.—Thin cross section of Sewickley coal from the middle of the bed. X200.

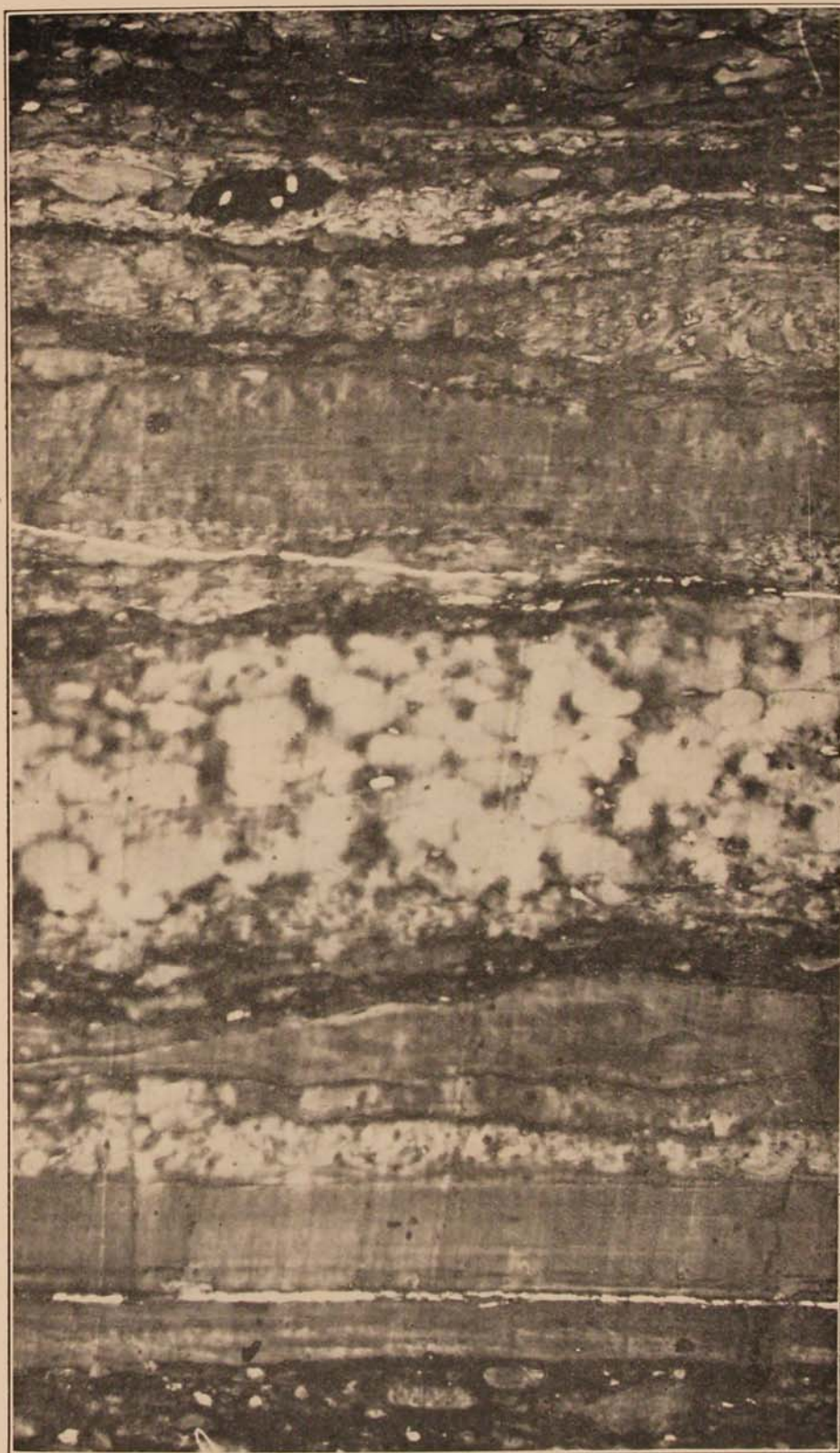


PLATE XXXII.—Thin cross section of Sewickley coal showing characteristic structures. X200.

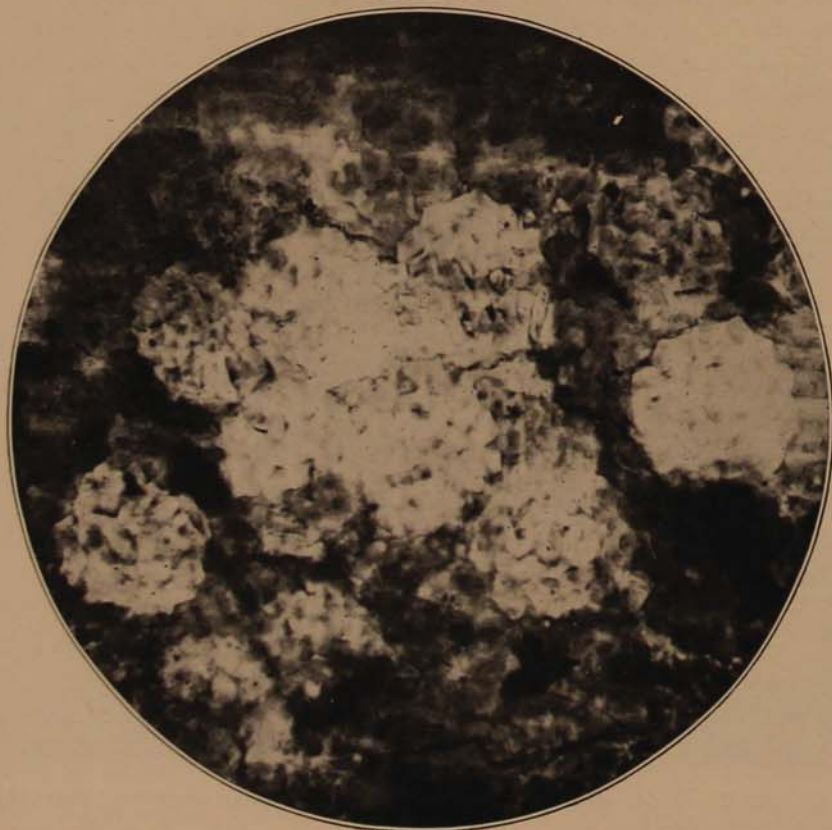
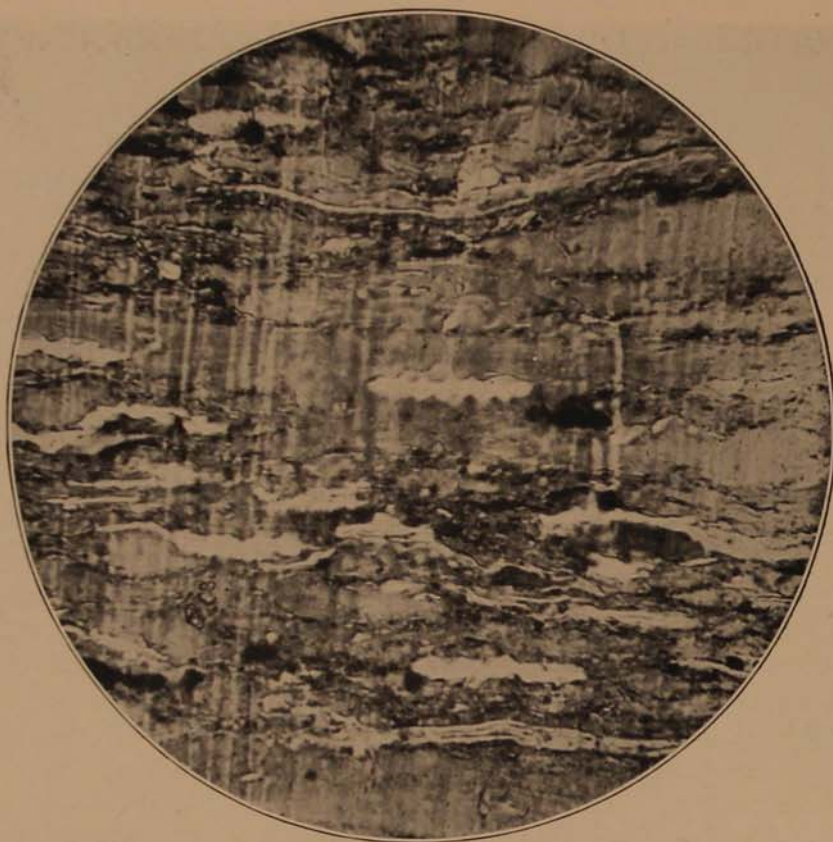


PLATE XXXIII, A.—Thin cross section of Sewickley coal showing characteristic spores. X200.

PLATE XXXIII, B.—Thin horizontal section of Sewickley coal showing the characteristic spore on the broadside.

STRATIGRAPHY OF THE DUNKARD SERIES NEAR  
CORE, WEST VIRGINIA

By EARL L. CORE,  
West Virginia University.

**Introduction.**

The area described in the following report includes portions of Clay and Cass Districts, Monongalia County, West Virginia, and portions of Perry and Dunkard Townships, Greene County, Pennsylvania, lying between the parallels of  $39^{\circ} 37'$  and  $39^{\circ} 47'$  north latitude and the meridians of  $80^{\circ} 4'$  and  $80^{\circ} 12'$  west longitude from Greenwich, the whole area being approximately 90 square miles. In this small area more than 750 feet of the Dunkard measures are exposed, beginning from their base on the Waynesburg Coal.

The territory is served by the Scotts Run Division of the Monongahela Railway, which runs east and west across the area, having been completed to Pentress in 1917. The Morgantown and New Martinsville Pike (the old Dunkard Creek Turnpike) now known as State Route No. 7, practically parallels the railway and is all improved or in process of improvement. Federal Route No. 19 runs southeast and northwest across the northern portion of the area, the paving on this route being completed in 1927. Besides these two main routes, the area is served by many cross connecting roads, several of which are improved.

The drainage is practically all through Dunkard Creek, which flows from west to east across the area, receiving from the south Statler Run, Dolls Run, Crosveys Run, and Wades Run; and from the north Blacks Run, Shannon Run, Bacon Run, Hobbs Run, and Colvin Run. Scotts Run and Indian Creek flow east and south, respectively, into the Monongahela River.

The topography is that of a deeply dissected plateau, the knobs in most places being 500 feet above the levels of the valleys. The largest extent of level land is along Dunkard Creek, where little prairies 0.5 mile wide are not uncommon. Along the smaller streams the valleys are V-shaped, the slopes steep and the flood plains at the bottom extremely narrow.

The population is rather scattered, agriculture being the principal industry, except at Cassville, where mining operations are carried on extensively. Several oil and gas companies have their offices in Core or carry on operations in the vicinity of that village. The other chief villages of the region include Hagans, Lemley Siding, Mooresville, Mt. Morris, and Statler Run.

The construction of State Route No. 7 through the region laid bare many formations hitherto poorly exposed in the section and led the author to make a detailed study of the stratigraphy of the entire area,

preparing the report in partial fulfillment of requirements for the degree of Master of Arts in the Department of Geology of West Virginia University. The present paper is an abstract of that much longer report.

#### Description of the Formations.

The highest formation to be identified with certainty in the region studied was the Lower Rockport Limestone, coming 35 feet above the Nineveh Coal, measured along a private roadway of the South Penn Oil Company, 0.6 mile southeast of Behler. It is here only about 6 inches thick, gray, and very hard. It came here about 35 feet below the top of the highest knob in the area (elev. 1600 ft. above sea level) and was not observed elsewhere.

Thirty-five feet of shales and thin sandstones come just beneath the Lower Rockport limestone and then we reach the Nineveh Coal. This coal seam, very persistent in western Monongalia and Greene counties, passes above the tops of most of the hills in this region. Its only observed outcrop was at an elevation of 1530 feet above sea level in the private roadway 0.6 mile southeast of Behler, mentioned above. It was here only 2 inches thick and quite impure.

About 80 feet below the Nineveh coal near Behler there occurs the massive Fish Creek Sandstone, so named from its famous outcrops along Fish Creek, in Greene County, Pennsylvania. In the region about Core its crop occurs near the tops of the ridges but even here it is a valuable source of building stone. At the Behler School it is about 30 feet thick, quite massive, and occurs in the form of great boulders of disintegration along the highway. On the Noah Wright Farm 0.5 mile north of Behler, its crop, 20 feet thick, was quarried to a considerable extent in 1928 for use in the construction of the Statler Run highway. The most spectacular exposure of the formation in the region studied is at the locality of the so-called Fox Rocks, an assemblage of great boulders of disintegration strewn over the face of the hill, 0.5 mile westward from Behler. The top of the ledge is here at an elevation of 1430 feet above sea level. The rock is quite massive, with a total thickness of more than 30 feet. The boulders are strewn over an area of more than 5 acres, the most remote being about a quarter of a mile away, at an elevation of 1190 feet above sea level. The larger boulders number about 10 or 15, with innumerable smaller ones, covered with mosses and ferns, or the larger ones with small trees and shrubs. One of the larger ones, about 1000 feet from the point of origin, at an altitude of 1300 feet, was 25 feet thick and 152 feet in circumference at the bottom, being shaped like a sugar bowl.

A few inches to a few feet below the Fish Creek sandstone there comes the coal called from its position, the Fish Creek. Its outcrop was noted at the road fork at Behler, at an altitude of 1380 feet above sea level, where the seam was 2 inches thick. Immediately beneath it

there occurs, at that point, about 2 feet of impure fireclay shale.

Below the Fish Creek fire clay shale there come some 30 feet of red and sandy shales which form in the highway at Behler the red clay so difficult to negotiate when wet. Fifty to seventy-five feet beneath the Fish Creek coal occurs in this region the thin Dunkard Coal seam, so named from its outcrop along Dunkard Creek, near Maple, Battelle District, Monongalia County. It is, at its best, not much more than a foot thick and is only 7 inches where measured in this locality, along the highway near the head of Smoky Drain, one mile east of Core, at an altitude of 1336 feet. Four inches of fire clay shale occurs at the horizon of this coal along the Core-Mt. Morris highway on the Henderson Hill, 1.5 miles south of Mt. Morris. A layer of fire clay shale 4 inches thick, at the horizon of the Dunkard coal, outcrops between the two sharp curves in the Core-Mooresville highway, 0.8 mile southeast of Mooresville.

About 45 feet below the Dunkard coal there occurs a double-bedded coal which has been designated the Jollytown from its crop near a village by that name in Greene County, Pennsylvania. It outcrops in a curve in the Smoky Drain highway, 1.5 miles northeast of Core, at an elevation of 1290 feet above sea level, where the following section was measured:

	Feet	Inches
Coal .....	0	2
Shale, gray .....	0	3
Coal .....	0	2

It is the Jollytown coal which crops in the Core-Mooresville highway, just below the lower curve, 0.8 mile southeast of Mooresville. Here the single bed noted, at an elevation of 1320 feet, was about six inches thick. It is exposed along the hill road leading west towards Statler Run, 0.5 mile west of Mt. Hermon church, where the following section was measured at an altitude of 1340 feet:

	Feet	Inches
Coal .....	0	4
Shale .....	0	8
Coal .....	0	3

This coal is, next to the Washington, the most persistent and important in the Dunkard series, being mined for local domestic purposes in both Clay and Battelle districts. It thins out eastward, however, and in this section is of no commercial importance. It is, nevertheless, an important key formation in the identification of the upper Dunkard formations.

Eight feet beneath the Jollytown coal along the Smoky Drain highway, mentioned above, comes the Upper Washington Limestone.

It is composed here of two ledges of gray and very hard stone, each about one foot in thickness, separated by a foot of shale. On the top of the knob 0.4 mile northeast of Holman, a crop of this limestone was observed, about one foot thick. It is this ledge that crops in the road along the Henderson Hill, 1.5 miles south of Mt. Morris, where it is one foot thick. An underlying limy shale, about 10 feet in thickness, is quite persistent and occurs in practically all the places where the Upper Washington limestone was noted. This formation, so extensively used for macadamizing the National Road in Washington County, Pennsylvania, is here too thin to be of economic importance.

About 10 feet under the Upper Washington limestone comes the Hundred sandstone, which is a gray and brown formation quite extensively quarried for building purposes near Hundred, in Wetzel County, West Virginia. In the region about Core, it receives its best development near the top of the knob, 0.4 mile northeast of Holman, where it forms great rugged cliffs, in places 45 feet high. The Hundred coal was not observed in the region studied and must be lacking, since its horizon is exposed in several places.

The interval between the Hundred and the Washington coals is frequently occupied in this locality by two sandstone ledges, which I. C. White has named the Marietta sandstones from their famous outcrop at Marietta, Washington County, Ohio, where they have long been quarried for grindstones. Between the two ledges occur some 60 feet of shales and thin sandstones. At the base of the Upper Marietta there occurs an impure coal that has been designated the Washington "A" coal. Its outcrop was observed along the Core-Mooresville highway, 0.5 mile southwest of Core, where 1 inch of coal and 6 inches of fireclay shale were measured. Along the creek bluff at Price a landslide has revealed this coal about 115 feet above the railroad, at an altitude of 1073 feet above sea level, where it was 1 foot thick. The interval between the Upper and Lower Marietta sandstones, in Wirt, Roane, and Calhoun counties, contains a very thick stratum of dark red shale (Creston), forming the famous red mud of that section of the state. These shales are here not nearly so well developed and may be no more prominent than several other red beds of this locality, as, for example, the 35 feet of dark red beds exposed in the sharp curve in the highway on Henderson Hill, 1.5 miles south of Mt. Morris, coming immediately beneath the Lower Washington limestone. The Lower of the Marietta sandstones occurs in this region about 60 to 75 feet below the Upper and about 5 to 15 feet above the Washington coal, frequently forming steep bluffs along the hillsides. It is from 10 to 40 feet in thickness. It forms a projecting ledge at the top of the deep railway cutting on Lemley Hill, 0.8 miles northeast of Lemley Siding, and its shelf can be traced readily all the way down Dolls Run to the juncture of the latter with Dunkard Creek. One of the most conspicuous outcrops of this ledge noted

was along the creek bluff at Holman, where it is 40 feet in thickness, massive, hard, forming a prominent cliff along the hillside for more than 0.5 mile, its face eroded by the elements into all sorts of fantastic shapes. Near the head of Pedlar Run, on lands owned by W. J. Wright, it has been quarried somewhat extensively, especially for use in the construction of the stone wall along the Dolls Run Cemetery in the village of Core. The pretty little waterfall in the brook 0.5 mile southwest of the mouth of Shannon Run is formed by this projecting ledge. Against the creek bluff opposite the residence of D. N. Lemley, 1 mile southwest of Mt. Morris, it forms a bare rock wall from 20 to 45 feet in height, its face eroded by the wind into many small cavities, at least one in the proportions of a cave which it was always the sport of adventurous boys to attempt to reach by climbing.

A few feet above the Washington coal in this locality there occurs a seam of impure, thin, slaty coal that has been designated the Washington "rider," on account of its approximation to the Washington bed. Its outcrop, about a foot in thickness, was observed along the Smoky Drain highway, 1 mile northeast of Core; and also along the Mt. Hermon-Statler Run road, 0.8 mile northeast of Statler Run, where it was 1.5 feet thick.

Immediately above the Washington Coal throughout this area occurs a bed of limestone which has been called by Stevenson the Lower Washington Limestone. It is quite persistent and is of great value in locating the underlying Washington coal when that seam may be concealed.

The Washington bed is the only coal in the Dunkard series of sufficient value to be classed as a minable vein. Even it is mined very little at present, owing to the presence of other much more valuable coals in the territory. This multiple-bedded coal was originally designated Brownsville, near which village (now known as Pentress) it was mined for many years for local use. Its present name was given on account of its fine development in Washington County, Pennsylvania. It has also been mined extensively for local use on the Kate Core Farm, near the mouth of Brushy Run, 0.5 mile northwest of Core. The vein was opened a few years ago on the Jacob Sines estate near the residence of Frank Myers, 1.2 miles northwest of Core, and some coal removed. On the Sines estate 1.8 miles northwest of Core, a splendid section was exposed in the construction of the new highway, where the coal was three feet thick. Smoky Drain flows across its crop 1.8 miles northeast of Core, near the residence of Mose Mathews, at an elevation of 1080 feet. Its outcrop in the road at the foot of the steep hill near the residence of Tabe McElroy, 2.5 miles south of Core, is at an elevation of 1100 feet above sea level. It is exposed in the railroad cut on the top of Lemley Hill, 1 mile northeast of Lemley Siding, at an elevation of 1270 feet above sea level. It is this seam which has been opened

above the railroad at Dunkard, opposite the residence of Thomas B. Keck. It crops in a little brook 0.5 mile southwest of the mouth of Shannon Run, where it has been mined to a limited extent for domestic purposes for more than half a century. It is exposed in the bed of the brook at the residence of Lemley Martin, 1.5 miles southeast of Holman, and has been removed to a slight extent by stripping. It outcrops 35 feet above the highway on the steep bluff at the Buckeye church and also along the Crosveys Run road, near the bridge over that stream, 2 miles north of Core, at an altitude of 990 feet. It may also be seen along the Statler Run-McCurdyville highway, 1 mile southeast of Statler Run, at an altitude of 1090 feet.

Beneath this coal there comes 10 to 30 feet of shales and sandstones (including the shaly Washington sandstone) and then occurs the one or more seams of impure coal that has been designated the Little Washington. Its outcrops are numerous in the region studied and are as varied as their number, in some places as many as four thin seams being recorded. It is nowhere of commercial importance.

There occurs quite generally near the base of the last mentioned coal a massive sandstone, very variable in its thickness, but of such prominence in the topography of the region that the author believes it worthy of especial note and has therefore applied to it the designation Dolls Run, from its excellent development along that stream. It is very hard, blue-gray in color, weathering gray, and, as above stated, quite massive. Along the old highway 0.6 mile north of Core, it is about 12 feet thick and has been quarried to a limited extent for building purposes, particularly in the construction of the residence of C. H. Core, in the village of Core. It is this ledge, 10-15 feet in thickness, that has been quarried at the mouth of Brushy Run, 0.5 mile north of Core, for use in the construction of the four railway and highway bridges over Dolls Run in the northern end of the village. In the highway cut just south of the Billy Eddy Hollow, 1.6 miles northwest of Core, this ledge presented a considerable obstacle to the construction forces, being more than 6 feet exposed, very hard and extremely difficult to cut out.

Beneath the Dolls Run sandstone there comes the silicious Bristol Limestone, quite persistent but commercially unimportant in this locality. It crops in the edge of the state highway 0.6 mile northwards from Core, where it is 2 feet thick. It crops in the bed of Smoky Drain, in the Sugar Grove Picnic Grounds, in the edge of the village of Core and is three feet thick, being quite hard. Its outcrop along the railroad, 0.2 mile southeast of Dunkard, is 8 feet thick. Near where the highway crosses Statler Run, 0.8 mile southwest of Price, the limestone outcrops along the stream immediately beneath the massive Dolls Run sandstone which forms the cliffs at that point.

The 40 to 50 feet beneath the Bristol limestone is made up mostly of shales and thin shaly sandstones, except in the northern part of the

area, where there occurs the massive Mannington sandstone, well exposed along Dunkard Creek and Shannon Run. Along the creek bluff opposite the residence of D. N. Lemley, 1 mile southwest of Mt. Morris, just north of the state line, it is 25 feet thick, massive, hard and gray. At the mouth of Bacon Run, 1 mile west of Mt. Morris, it is 15 feet, massive and hard. It was quarried here for the construction of the macadam road from Mt. Morris to the mouth of Shannon Run. Near the mouth of Shannon Run it is now being quarried for use in the extension of the road up that stream. Its outcrop in this quarry is 15 to 20 feet thick.

The Waynesburg "B" Coal comes directly beneath the Mannington sandstone in the outcrops mentioned in the above paragraph and is about 11 inches thick. It has been mined by stripping at its crop in the bed of Bacon Run, near the mouth of that stream, Aaron Rose, a resident of that section, declaring he was able to mine 100 bushels of good coal in a two-day period.

Immediately beneath the Waynesburg "B" coal there occurs in this region a local limestone which the present author for convenience has designated the Shannon Run Limestone, from its exposure on Shannon Run, 2 miles west of Mt. Morris, where it was first observed, although not named, by J. J. Stevenson in 1875. It is here a foot in thickness and has eroded to a greater extent than the overlying coal.

Thirty to thirty-five feet beneath the Waynesburg "B" coal there comes the Colvin Run Limestone, which is exposed at the foot of the hill along the highway opposite the residence of D. N. Lemley, 1 mile southwest of Mt. Morris. It is here 3 feet in thickness, buffish and impure. At its type locality, along Colvin Run, 0.7 mile north of Mt. Morris, it is 3 feet thick, hard and gray.

The Waynesburg "A" Coal, the lowest in the Dunkard series, is quite persistent but its horizon is not exposed except in the northern portion of the area. Its exposure was noted just beneath the Colvin Run limestone, along Colvin Run, 0.7 mile north of Mt. Morris, where it was 2 feet thick; also at the highway bridge over Hobbs Run, 0.2 mile west of Mt. Morris, where the same thickness was observed.

The Mt. Morris Limestone comes about 2 feet beneath the above described coal at the highway bridge over Hobbs Run, 0.2 mile west of Mt. Morris, the only point where its outcrop was observed. It was here about 2 feet in thickness.

About 2 to 10 feet below the Mt. Morris limestone there comes the most important sandstone of the Dunkard series, designated many years ago by the First Geological Survey of Pennsylvania from its excellent development at Waynesburg. It is massive, gray and brown (the only conglomeratic sandstone in the series), ranging in thickness from 20 to 75 feet. It is known locally among oil and gas men as the Bluff sand. One of the finest exposures of this rock is in the cut made

for the new state highway 0.5 mile west of Cassville, where the construction forces worked for several weeks blasting their way by a 26-foot cut through this difficult formation. Along the highway leading towards Dunkard Ridge, 1 mile northeast of Cassville, a delightful little glen has been occasioned by the presence of this rock. This sandstone, more than 50 feet thick, forms the high cliffs along the highway at the mouth of Colvin Run, 0.7 mile north of Mt. Morris. The north end of the old covered bridge over Colvin Run at that point is supported naturally by a huge block of this sandstone.

The Cassville Plant Shale is the lowest member of the Dunkard series. Near the village of Cassville it is 4 to 10 feet in thickness, full of fossil plants and insects. Its outcrop occurs immediately above the Waynesburg Coal and may be observed where that coal is opened, as at the mine of the Barbara Coal Company, 0.5 mile west of Cassville; the Cass Hill mine, 0.5 mile west of Cassville; the mine of the Dolls Run Coal Company, at Lemley Siding (a shaft); the Sutton mine, 1 mile northwest of Cassville; and the Wade mine, 1 mile southwest of Mt. Morris, as well as several others in the vicinity of that village.

#### Economic Importance.

Although there are 12 coal beds mentioned as occurring in the Permian measures described in this report, yet of these the Washington is the only one classed as minable and even it is of slight importance at present, owing to the presence of other much better coals in the region. The limestones and fire clay shales are likewise too irregular and limited in extent to be of importance commercially.

Apparently, the Dunkard formations of the greatest value to the people of this region are the massive sandstones, which promise to afford an unlimited quantity of good stone for use in the construction of the many unimproved roads of the area. Of these formations the following are available, those being marked with a star having been already used in this region:

- \*Fish Creek sandstone.
- Rush Run Sandstone.
- Jollytown sandstone.
- Hundred sandstone.
- Upper Marietta sandstone.
- \*Lower Marietta sandstone.
- \*Dolls Run sandstone.
- \*Mannington sandstone.
- \*Waynesburg sandstone.

In conclusion, the author wishes to express his cordial thanks to Dr. John L. Tilton, of the Department of Geology of West Virginia University, for his constant inspiration and assistance during the progress of this research.



FIG. 1.—Scotts Run Railway cut on top of Lemley Hill, 0.8 mile northeast of Lemley Siding. Ls in the figure is Lower Washington Limestone.



FIG. 2.—Cliff along the old state highway, 0.5 mile north of Core. The overhanging rock (W) at the top is the Washington Sandstone. Three seams of the Little Washington Coal (C) are found in the shales between this ledge and the Dolls Run Sandstone (D) 10 feet below. The Bristol Limestone (B) outcrops in the edge of the road.

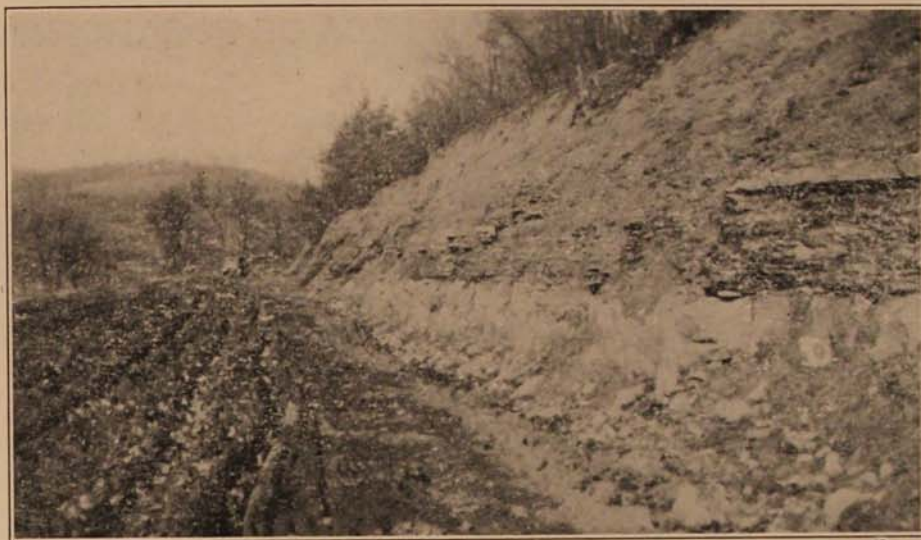


FIG. 3.—Dolls Run Sandstone disappearing beneath bed of highway, 1.6 miles northwest of Core.

#### Literature.

1. Monongalia-Marion-Taylor Report, W. Va. Geol. Surv. Ray V. Hennen. 1913.
2. Sec. Geol. Surv. of Pa. J. J. Stevenson. Vol. K. 1875.
3. Bull. 65. U. S. Geol. Surv. I. C. White. 1891.

TRILOBITES OF THE CHERT BEDS OF POCAHONTAS  
COUNTY

By ANDREW PRICE,  
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The discovery of trilobites in a peculiar rock formation in Pocahontas County is the subject of this report to the West Virginia Academy of Science. It is considered to be due to this scientific body because it was field work on the part of one of its members that found this interesting fossil so rare in West Virginia.

Pocahontas County has for its eastern boundary the divide known as the Allegheny Mountain. This county has a greater number of miles of the crest of the Allegheny than any other county either in West Virginia or any other state. It has perhaps a frontage of near seventy miles on this border all marked by the division of the waters. It is perhaps a fact that in Pocahontas County the crest of the Allegheny Mountain is not the true escarpment of the Allegheny Plateau, for the reason that just west of the main Allegheny Mountain is a remarkable mountain caused by the folding of the strata. This mountain has been cut in two in many places by the gorges which drained the temporary lakes that formerly lay between it and the Main Allegheny, and the mountain changes its name at every place that it is broken. It is known from north to south by the names of Buffalo, Michaels, Browns, Brushy Lick, and Beaver Lick mountains.

It is rich in marine fossils and in length is perhaps sixty miles long: That the mountain was once one long ridge is clearly demonstrated by observing the anticlinals on either side of the bisecting streams. The formation includes both the Devonian and Silurian, strata of both series being exposed. Another peculiar feature of the region dominated by this folded mountain is that it marked the boundary of a heavy growth of white pine timber in former years. More than a half a billion feet of white pine timber has been taken off of this section, and it is unusual to find any white pine timber this far south. It may be mentioned that the land reproduces white pine. It is a remarkable thing that the bounds of rich fossiliferous country should have been so plainly marked by the bounds of this wonderful growth of timber.

Over the whole length of this mountainous tract, on both slopes, an unusual rock formation was observed years ago, which for the want of a better name was called chert. It was used for road building. While it was in layers, yet it disintegrated under the power of the thrust of a steam shovel and was ready to be laid down in size ranging from that of an egg upwards to chunks of something like six inches in diameter. When built into a road bed it turned into dust and cemented together and was in great demand for its cheapness and availability.

The bed appeared to be about seventy feet thick, extending the whole length of the folded mountain, bent over its entire width, the whole stratum forming an upheaved bed about five miles broad and sixty miles long. For road work, pits were opened at convenient places. In Pocahontas County alone more than fifty miles of State highway was built out of it, the only kind of rock used from bed to surface.

The place of this chert stratum was next to the Oriskany sandstone, in the Lower Devonian. The Oriskany sandstone has the same fossils and general appearance as the glass sand mined at Berkeley Springs, in Morgan County.

The word chert is used here because it is accepted by the local people and is a word of common use wherever this road building material is under discussion. It is perhaps an impure limestone, stained with iron to a considerable extent.

Paleontologists were interested in finding fossils in this formation. As is well known the Oriskany sandstone is a most prolific source for some of the most striking and vivid reproductions of the forms of ancient life. But the chert beds seemed to be devoid of signs, and even yet with the sole exception of the one chert pit hereinafter referred to, there have been no definite shapes of marine animals discovered.

These pits where the steam shovels had worked gave a good opportunity to examine for fossils. The strata were tilted and it was customary to work through the strata and then move long ways on the mountain foot until sufficient material had been excavated to cover the near by miles of highway, and then move the machinery to some place on another stretch of road where the chert appeared.

For a long time no fossils were found but eventually in the early fall of 1928, at a gravel pit about six hundred feet long, at Knapps Creek, at the place called Sunset, on G. M. Sharp's land, after several days, a trilobite was picked up. In the abandoned works there were hundreds of thousands fragments and it was in the examination of these broken pieces that a large number of interesting fossils were found.

In addition to the trilobites some very perfect sponges were found as well as a variety of brachiopods. Also some well defined crinids. One large and perfect fossil of a sponge with a smooth, leather-like underside had clinging to it six shell-fish which were evidently parasites.

These shells were about as big as silver half dime pieces and it is an unusual experience to find clear evidence of parasites in fossils.

Among the several hundred specimens of trilobites found in this formation there are but two outstanding types: *Dalmanites pleuroptyx* and the *Homalonotus* types. There seems to be a type which has been named *Dalmanites berkeleyensis*, which in appearance partakes somewhat of the nature of the extremes mentioned above.

In size these specimens ranged from about an inch in their greatest dimension to those which might have been as much as two feet long.

Of course in the very large ones there was no one fragment complete enough to give an adequate impression of the full form of the animal, but the size of the rachises in the larger animals compared to the more perfect forms of the smaller specimens, enable an intelligent estimate to be made.

As usual the tail parts or pygidiums were by far the most numerous and while some complete fossils were found the best defined were heads that had been broken off from the hinder ends, and pygidiums with rachises that lacked the head.

A number of heads were found with well defined eye places, but only one head with plain compound eye was found. In this specimen, the lenses of something like sixty in number were visible without a magnifying glass.

The trilobite partakes of the nature of the modern crustacean more than any other animal, and yet there is marked similarity to the beetle, when we consider that the beetle has shields over its wings, and it is a subject of speculating curiosity whether fossils of trilobites had anything to do with the scarabs of Egypt.

## SOME ASPECTS OF THE POTTERY INDUSTRY OF WEST VIRGINIA. I. RAW MATERIALS

By W. A. KOEHLER,  
College of Engineering, West Virginia University.

Sometime prior to 1785 "Master" Foulk established at what is now Morgantown, a pottery which was probably the first west of the Alleghenies. None of Foulk's wares are known to have been preserved. About 1790 John W. Thompson, a lad of 10 was apprenticed to Foulk, and later succeeded Foulk in the business. They made their pottery from the Quaternary clays from the banks of the Monongahela, and their ware would be classed as terra cotta. The ware, consisting largely of tableware, was glazed with a yellow lead glaze, the lead being obtained mainly from the linings of tea boxes. John Thompson was later succeeded by his son, Greenland Thompson, who was very fond of incorporating designs of natural objects as decorations. Examples of his wares are still to be found in homes in and about Morgantown, and also in the U. S. National Museum at Washington. Although this, the first pottery of the state, produced table ware; the first whiteware was not manufactured until 1879 at Wheeling.

In 1839 James Bennett started a pottery, producing yellow ware, at East Liverpool, Ohio. Soon other potteries were attracted to the same place, and due to the topography of the place, potteries were crowded over to the West Virginia side of the river. Thus briefly was started the pottery industry of this state, and to-day we have 24 potteries producing whitewares, including earthenware, china, sanitary ware, electrical and refractory porcelain and floor and wall tile.

In this paper I want to present briefly a survey of the raw materials used by these potteries. By "whiteware" we understand that type of fired clay ware which is white due to the inherent whiteness of the materials which compose it. Most types of whiteware are glazed, the glaze being a clear glass. In order to produce this whiteness, the clay, feldspar, and flint which make up the body, must themselves be white when fired, and since clay is the predominant body material, we pay considerable attention to the nature of the clay. Generally manufacturers of whiteware feel that china clay, obtained from England is a very important ingredient in their wares. English china clay has long been noted for its uniformity and whiteness. However, it is interesting to note in this connection that Wedgwood once considered American clays an important constituent of his wares.

Of the 24 potteries in this state, there are 21 that use English china clays, leaving three that use domestic china exclusively. Most potteries use both, English and domestic clays. Many of our domestic china clays give a slight creamy tint to the wares, so that manufacturers have used

it only up to what they consider the safe limit. This limit, however, has been gradually raised, and may possibly some day reach nearly 100 percent. The domestic china clay used by West Virginia potteries is obtained from North Carolina, Georgia, and Florida. From the various county reports of the State Geological Survey we are led to draw the conclusion that we cannot expect to find a white burning pottery clay in this state, although no systematic investigations have been made to determine this. Some years ago, one pottery producing sanitary ware, did use some local clays, but later discontinued the practice. Some clay deposits in the state seem to have white burning properties, but the suitability of the clay for pottery and the extent of the deposits would have to be determined very carefully. The amount of china clay produced in the United States has been gradually increased and in 1927 amounted to 450,000 tons, it having increased nearly 200% since 1919. The imports of English china clay have also increased during this period but the increase was less than 90%, so that at present more china clay is produced in the United States than is imported from England. The costs of English china clay and Georgia china clay delivered to West Virginia potteries is approximately \$30.00 and \$23.00 respectively. In one pottery producing sanitary ware, the difference in price of these two clays amounts to about \$20.00 per kiln of ware, which has a value of about \$1000.00.

In recent years, ivory colored ware has become very popular. Since whiteness is not desired for this purpose, English china clay is not as important as it is for strictly whiteware, and a large number of recipes for ivory bodies dispense with English china clay altogether.

In addition to china clay, the pottery body requires a ball clay. Ball clay imparts plasticity to the body which improves its workability, and also increases the strength of the green ware before it is fired. Ball clays have the peculiarity of almost invariably firing with a slightly yellow tint, even though the iron content may be less than that of a white burning china clay. The ball clay, therefore, is kept to the lowest practical limit for strictly whiteware, and the slight yellowish tint it imparts to the ware can be masked by a small amount of cobalt oxide added for this purpose. The blue cobalt acts much in the same way that blueing does in laundrying. Two West Virginia potteries use no English ball clays, and three use English ball clays only. These three manufacture vitrified hotel china. English ball clays are preferred for certain purposes on account of their greater strength and because they possess a longer vitrification range than do American balls. Practically all the domestic ball clays come from western Kentucky and Tennessee. No investigation has been made to determine whether or not West Virginia has any ball clays suitable for whiteware manufacture. Our general knowledge of our state geology does not permit us to answer the question one way or another.

Feldspar is another important raw material for pottery bodies. Local potteries obtain their feldspar from Maine, North Carolina, Tennessee, South Dakota, and Canada. Since igneous rocks are almost entirely absent, we would not expect to find feldspar in West Virginia.

Flint, finely pulverized, is another important body material and our state has an excellent deposit at Berkeley Springs, and 16 of our potteries use this flint. Flint from Pennsylvania, Illinois, Ohio, and Tennessee is also used by some of our potteries. Since approximately one-third of the body for white and ivory wares consists of flint, it would seem that developments of new deposits in the state might prove valuable. This again would require a careful investigation.

In addition to the raw materials for the bodies, potteries use large amounts of sagger clays. Saggings may be likened to unglazed jars made of refractory clay. The wares to be fired are placed in these saggings for protection and the saggings with the wares are placed in the kiln for firing. A sagger will have a life of about 12 to 16 firings. The replacement of saggings is one of constant expense and worry to the pottery manufacturers. We have good reason to hope that West Virginia may have deposits of clays suitable for sagger manufacture. If deposits of excellent quality could be found there could be established in this state a very profitable industry. At present, potteries obtain their sagger clays from New Jersey, Ohio, Kentucky, and Tennessee.

It will, therefore, be seen that with the exception of flint, the potteries of West Virginia obtain all their raw materials from without the state. There seems no prospect for the state to be able to supply the feldspar and there may be considerable doubt about china clay. Ball clays may or may not be available, but we may be quite hopeful about finding sagger clays. A careful investigation of our clays and other raw materials will guide us definitely in the development of our resources. It is hoped that such a programme of investigation may soon be undertaken.

## NON-INVOLUTORIAL TRANSFORMATIONS BELONG- ING TO A SPECIAL LINEAR COMPLEX

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(Abstract)

We here consider the most general non-involutorial Cremona space transformation which has the property that each point of space and its image lie on a ray of a special lineal complex  $\Gamma$ , a single pair on a generic ray. Such a transformation  $T$  is said to belong to the complex  $\Gamma$ .

Transformations of this kind have been studied synthetically by M. Pieri\*.

In the present paper, which was recently submitted to the American Journal of Mathematics, the equations of  $T$  are derived and studied by analytic methods. A number of errors are detected in the synthetic discussion given by M. Pieri which cause most of his work to be incorrect.

It is correctly shown by Pieri that the loci of points  $P$  and  $P'$  in a linear  $\Gamma$ -congruence are surfaces  $F_n : d^{n-2}g$  and  $F'_{n-1} : d^{n-2}g$  respectively, where  $d$  is the directrix of  $\Gamma$  and  $g$  is the second directrix of the lineal congruence. If we take  $d \equiv x_1 = x_2 = 0$ , the  $\infty^4 |F_n|$  may be written

$$(1) (\alpha_{13}y_1 + \alpha_{23}y_2 - \alpha_{34}y_4) U - (\alpha_{14}y_1 - \alpha_{42}y_2 + \alpha_{34}y_4) V = 0,$$

$$\text{where } U = \sum_{i=2}^n u_i x_1^{n-1} x_2^{i-2}, \quad V = \sum_{i=2}^n v_i x_1^{n-1} x_2^{i-2}, \quad u_i = \sum_{k=1}^4 a_{ik} x_k$$

$$v_i = \sum_{k=1}^4 b_{ik} x_k. \quad \text{The } \infty^4 \text{ linear } \Gamma\text{-congruences are the section of}$$

$\Gamma \equiv p_{12} = 0$  by

$$\alpha_{12} p_{12} + \alpha_{13} p_{13} + \alpha_{14} p_{14} + \alpha_{23} p_{23} + \alpha_{42} p_{42} + \alpha_{34} p_{34} = 0.$$

It is easily shown that these  $\infty^4 |F_n|$  have  $d$  for an  $(n-2)$  fold tact locus. This important fact was not discovered by Pieri.

If  $g$  meets  $d$  the corresponding  $F_n$  is composite, being

$$(2) (\alpha_{13}y_1 + \alpha_{23}y_2) (a_{23}U + a_{42}V) = 0.$$

The surfaces of the pencil  $|F_{n-1}| \equiv a_{23}U + a_{42}V = 0$  contain  $d$  to multiplicity  $n-2$  instead of  $n-3$  as Pieri states. Furthermore, Pieri is mistaken in assuming that  $d$  is a tact locus for  $|F_{n-1}|$ .

The equations of  $T$  and  $T^{-1}$  are found to be

$$(3) y_1 = x_1 J_1', \quad y_2 = x_2 J_1', \quad y_3 = x_3 J_1' - U(x)K(x), \quad y_4 = x_4 J_1' + V(x)K(x),$$

and

$$(4) x_1 = y_1 J_1, \quad x_2 = y_2 J_1, \quad x_3 = y_3 J_1 + U(y)K(y), \quad x_4 = y_4 J_1 - V(y)K(y)$$

respectively where  $K = UV' - U'V$ ,

\*Sulle trasformazioni birazionali dello spazio inerenti a un complesso lineare speciale, Circolo Matematico di Palermo, vol. 6 (1892) pp 234-244.

$$J_1' = U'(x) \left[ V'(x) \frac{\partial U(x)}{\partial x^3} - U'(x) \frac{\partial V(x)}{\partial x^3} \right] - V'(x) \left[ V'(x) \frac{\partial U(x)}{\partial x^4} - U'(x) \frac{\partial V(x)}{\partial x^4} \right],$$

$$J_1 = U(y) \left[ V(y) \frac{\partial U'(y)}{\partial y^3} - U(y) \frac{\partial V'(y)}{\partial y^3} \right] - V(y) \left[ V(y) \frac{\partial U'(y)}{\partial y^4} - U(y) \frac{\partial V'(y)}{\partial y^4} \right].$$

The orders of  $T^{-1}$  and  $T$  are respectively  $n-2n'-3$  and  $2n+n'-3$ . The homoloidal webs of  $T$  and  $T^{-1}$  are respectively

$$\infty^3 | F'_{n+2n'-3} | : d^{n+2n'-6} C'^2_{2n'-3} \vee'_{4n+2n-10} \text{ and}$$

$$\infty^3 | F_{2n+n'-3} | : d^{2n+n'-6} C^2_{2n-3} \vee_{2n+4n'-10}.$$

It is found analytically that  $d$  is an  $n'-2$  (or  $n-2$ ) fold tact locus for  $|F'_{n+2n'-3}|$  (or  $|F_{2n+n'-3}|$ ). This partial contact of the surfaces of the homoloidal webs was not discovered by Pierri.

The jacobian surfaces of  $T^{-1}$  and  $T$  are respectively  $J_1^2 J_2 J_3 = 0$  and  $J_1' J_2' J_3' = 0$ , where

$$J_1 = U \left( V \frac{\partial U'}{\partial y_3} - U \frac{\partial V'}{\partial y_3} \right) - V \left( V \frac{\partial U'}{\partial y_4} - U \frac{\partial V'}{\partial y_4} \right),$$

$$J_2 = U \left( V' \frac{\partial U'}{\partial y_3} - U' \frac{\partial V'}{\partial y_3} \right) - V' \left( V' \frac{\partial U'}{\partial y_4} - U' \frac{\partial V'}{\partial y_4} \right),$$

$$J_3 = U \left( V \frac{\partial U}{\partial y_3} - U \frac{\partial V}{\partial y_3} \right) - V \left( V \frac{\partial U}{\partial y_4} - U \frac{\partial V}{\partial y_4} \right),$$

$$J_1' = U' \left( V' \frac{\partial U}{\partial x_3} - U' \frac{\partial V}{\partial x_3} \right) - V' \left( V' \frac{\partial U}{\partial x_4} - U' \frac{\partial V}{\partial x_4} \right),$$

$$J_2' = U' \left( V \frac{\partial U}{\partial x_3} - U \frac{\partial V}{\partial x_3} \right) - V \left( V \frac{\partial U}{\partial x_4} - U \frac{\partial V}{\partial x_4} \right),$$

$$J_3' = U' \left( V' \frac{\partial U'}{\partial x_3} - U' \frac{\partial V'}{\partial x_3} \right) - V' \left( V' \frac{\partial U'}{\partial x_4} - U' \frac{\partial V'}{\partial x_4} \right).$$

It is easily shown that  $J_2$  and  $J_3$  (or  $J_2'$  and  $J_3'$ ) are tangent  $n-2$  (or  $n'-2$ ) times in  $d$ , another case of partial tangency unnoticed by Pierri.

## MINING EDUCATION IN WEST VIRGINIA HIGH SCHOOLS

By C. E. LAWALL,

Professor of Mining Engineering, West Virginia University.

With the object of adapting high school vocational courses to the industrial needs of the community, a few high school officials in West Virginia working with the School of Mines of the State University decided to try an innovation this year. The purpose of this experiment was to teach coal mining in two high schools situated in mining communities. We thought that if a coal mining course would be included in the list of optional courses offered in the high school, it might interest some of the high school boys, and if the course were properly taught it would undoubtedly be of inestimable value to those boys who later decided to take up mining work as their vocation.

This coal mining course was started last September in the Berwind and Gary high schools in West Virginia. The high school officials in their conferences with us decided that we should work up the outline of this course and they would assign the science teachers of the schools as instructors, with the understanding that we would help these instructors with this work in every possible way. We consented to all this and submitted an outline to the school officials which they are following this year.

We also furnished the schools with a list of all the apparatus and equipment needed to teach this course, and suggested a number of books, papers and pamphlets on mining which should be obtained to help the instructor in his work and to start a reference library on mining in the high school. As a further aid to the instructor, we wrote a series of lesson sheets on parts of the outline and distributed these lesson sheets to the students.

This work has been going along nicely from the start, due mainly to the interest and co-operation it has received from the local school officials, the State Superintendent of Schools, and from R. M. Lambie, of the State Department of Mines, who has actively supported the work in every way. The interest of the school officials is shown by the fact that one of the high schools purchased all the equipment and books suggested on our list, and this school is now very well equipped to teach the course. The other high school is gradually getting its equipment together and in making a study of this work recently the district superintendent of schools told me that he was thoroughly convinced of the importance and value of this work in the high school, and would purchase everything the instructor needed to teach this course. So next year West Virginia will have at least two high schools fully equipped to teach coal mining courses. With the mining equipment and

apparatus in the high schools, the mines and mining machinery close at hand for the laboratory work, the only thing needed to make conditions ideal for the boys to study mining is a competent teacher.

Selecting competent teachers for this work is a very important matter. It is a work which requires special aptitudes, and when the man who has these in ample degree is found he usually is not interested in a teaching position. Teachers in vocational subjects must know their subjects well to impress the students, and high school teachers with a good knowledge of mining are not plentiful. Fortunately at Berwind and Gary we had no trouble regarding this condition. Both of these high schools are in a district where the Mining Extension Department of the University maintains a full time instructor. This instructor conducts Mining Extension night classes each week at Berwind and Gary, and the high school instructors who are teaching the mining courses attend these night classes regularly.

One high school instructor attends several Mining Extension classes each week and the other instructor has been attending our Mining Extension classes for several years, and has also worked around the mines. With their mining background and the assistance they have been getting from our Extension instructor they have been having very little trouble with the mining courses. By attending the Mining Extension classes they not only get academic material for their courses but from the discussions in the classes they get valuable suggestions and viewpoints from the practical men of the mines which help them in their teaching work.

Our Mining Extension instructor visits each high school at least twice each week and frequently teaches the classes and assists the instructor when he takes the boys on field trips. Of course, field trips are very important in any vocational work because they correlate the practical with the academic work, and this part of the work is receiving much attention. Some of the trips outlined for this course included geology trips which will point out the coal seams in the vicinity; a trip to the fan house in connection with their studies in ventilation; a trip to the chemical laboratory in connection with the study of mine gases, and so an innumerable number of important things can be found and studied on the field trips to the mines.

When the field trips are taken an effort is made to have a company official, or some one else well versed in the subject to be studied, accompany the party and explain to the students the things that are seen. Young men have a great deal of respect toward the man engaged in practical work when he is describing his particular line of work to them, and usually he can impress on them the importance of his work better than anyone else.

This course is elective for seniors and the prerequisites or accompanying subjects for the course should be chemistry and physics. Both

high schools are holding an hour session every day which will continue for a year, and on completion of the course the students are given one hour credit for this work. At Gary, twenty-eight boys wanted to enroll for this course this year, but the school officials limited the class to ten men for the first year. The Berwind high school has also ten men enrolled in the course. It is a modest beginning but it is arousing an interest in other communities, and other high schools are planning to offer this work to their students next year.

What the ultimate success of this work will be, must be gauged several years hence when we can ascertain the definite results it has produced for the boys who have taken the course—that is whether it has helped some boys to make good at the mines or whether it has helped some boys to discover their ability for mining work and induced them to go to a mining school for further training. It will certainly impress all the boys with the importance of the coal industry to the state of West Virginia, and the relation of the coal industry to the other industries, and will, I believe, give them a new attitude toward mining work.

The influence this course might exert on some of the boys stimulating in them an interest in mining, and probably inducing them to go to college is the thing that interests me very much. During the past several years, relatively few men have been enrolling in our mining schools, so that now not enough men are graduating in coal mining engineering to fulfill the normal demands of the industry for technical mining men. But when one considers how little has been done to acquaint young men with the opportunities and need for technical men in the coal industry and to attract the right kind of young men to it, one is not surprised why so few young men are interested in mining engineering.

These high school courses I hope will do something toward interesting promising young men in mining work and give them a new attitude toward this important industry, so that eventually the coal industry will have proportionally as many highly trained technical men in its ranks as other industries. If the interest these high school boys are taking in this work is indicative of this change of attitude, I am sure it is taking place.

## ON POLYHEDRA AND POLYTOPES

By CLARENCE N. REYNOLDS,  
Department of Mathematics, West Virginia University.

(Abstract)

In this paper the author proves that the truth of Euler's theorem for those polyhedra in which three edges are incident with each vertex implies the truth of Euler's theorem for all polyhedra. He then generalizes this proposition for polytopes in spaces of  $n$  dimensions.

In the further study of polyhedra the author obtains a group of new equations involving the numerical topological characteristics of polyhedra which replace and extend earlier inequalities due to Catalan. From these equations he obtains more adequate restraints upon those numerical specifications which may be satisfied by actual polyhedra.

Abstract read, through the courtesy of Dr. John A. Eiesland, before the mathematical section of West Virginia Academy of Science, at Charleston, W. Va., April 26, 1929.

## A "PATCH" THEORY OF PHOTOELECTRIC FATIGUE

By GEORGE B. WELCH,  
Department of Physics, Marshall College.

(Abstract)

In order to account for certain phenomena of photoelectric fatigue, it is assumed that contamination may take place at discrete areas of the surface of the material so that certain portions of the original surface will continue to exist and to eject electrons corresponding to an incident frequency which need not increase so long as any portion of the original surface continues to exist. This leads to the conclusion that the photoelectric threshold should show no shift until contamination has spread over the entire surface. It is also assumed that these "patches" increase in area and in thickness, thereby producing a diminution in the photoelectric current. These conclusions have been verified experimentally.

The theory is further prepared to account for results in case the surface contamination should facilitate the ejection of electrons. In this case the photoelectric current increases, and the rate of increase decreases with increasing frequency. There is also a definite shift in the threshold towards the long wave-lengths. These conclusions have not been verified experimentally.

Although there is some evidence that gaseous contamination is the principal factor in producing fatigue, the results are by no means unequivocal.

Acknowledgement is made of the work of Woodruff, and of Richardson and Young.

CERTAIN GROUPS OF ORDER  $8n$  WITH THREE  
GENERATORS

By R. M. MATHEWS,  
Department of Mathematics, West Virginia University.

(Abstract)

Consider two commutative operators  $s_1$  and  $s_2$  of period 2 and an operator  $t$  of period  $m$  which transforms them into each other. We find that  $t$  is of even period:  $m=2n$ ; that such sets of operators exist as substitutions for every  $n$ ; that  $t$  is commutative with the product  $s_1 s_2$ ; that the three operators generate a group of order  $8n$  in general. These groups fall into two categories according to the parity of  $n$ , and we prove the following two theorems:

That non-obelian finite group of order eight times an odd number which is the extension of the dihedral group of order eight by a commutative operator of period  $n$ , may be generated always by the commutative operator of period two and an operator of period  $2n$  which transforms each into the other.

For every number  $16k$  there exists a non-obelian group of that order generated by two commutative operators of period two and an operator of period  $4k$  which transforms each into the other and has no power equal to their product. If this product is equal to the  $n$ th power of the third operator, the resultant group is of order  $4n$ .

SOME TECHNICAL FEATURES OF THE NEW  
CHARLESTON BRIDGE

By R. P. DAVIS,

Professor of Structural and Hydraulic Engineering,  
West Virginia University.

**General:** The new free bridge now being built over the Kanawha River in the city of Charleston is located downstream about one and one-half miles below the mouth of the Elk River. At the present time there are three bridges across the Kanawha River within the city limits. One bridge near the center of the city known as the South Side bridge, connects the main part of the city with the south side at the C. & O. Railroad depot. This was built about thirty-five years ago as a toll bridge and later became free by purchase. It has a width of roadway of 19 feet. Another bridge known as the Kanawha City bridge, built about fourteen years ago, is at the eastern end of the city  $2\frac{1}{2}$  miles above the South Side bridge and forms a connection with Kanawha City. It was built as a toll bridge and was made free in 1928 by purchase. It has a roadway of 23 feet and is double-tracked for interurban street railway service. The third bridge is a railroad bridge built in 1908, on which is carried a highway bridge floor on cantilever brackets. This structure is located at the west end of the city a little less than one-half mile above the site of the new bridge and 1.7 miles below the South Side bridge and serves the community of South Charleston. It is a toll structure.

The three above mentioned existing bridges have to serve not only the local needs but they are also linked in the state and federal road systems. All through traffic on the Midland Trail, now Federal Route 60, must cross the river at Charleston as this route is on the south side of the river west of Charleston and on the north side east of Charleston. Likewise all north and south traffic must cross the river. The rapid growth of industrial Charleston west of the city together with the heavy through traffic has resulted in extreme congestion on the South Side bridge; particularly so as much of the traffic which would normally use the west-end toll bridge, goes over this bridge to save toll charges.

In 1928 a bond issue of \$1,250,000 was voted by Charleston and Loudin districts of Kanawha County to provide for the construction of a new free bridge at the west end of the city and for the freeing of the Kanawha City bridge at the east end. Of this amount \$350,000 was used to purchase the latter bridge, leaving \$900,000 available for the new bridge. The Kanawha City bridge was purchased in the fall of 1928. The contract for the substructure of the new free bridge was awarded to the Atlantic Bridge Company on January 18, 1929, the

work to be completed by the end of July, 1929. The contract for the superstructure was awarded the Fort Pitt Bridge Works on April 10, 1929, the work to be completed the last of January, 1930.

**Dimensions.** The new free bridge will have a roadway width of 40 feet, good for four simultaneous lanes of traffic; and two sidewalks, each 8 feet wide, this making the total effective width 56 feet. The extreme length of the bridge is 1986 feet, the length of the superstructure being 1770.5 feet center to center of end bearings. With a floor area of 111,200 square feet, this will be the largest bridge in West Virginia. Starting at the north end of the bridge on Patrick Street at Third Avenue the bridge will be on a 7 percent rising grade. The first 135 feet will be a part of the abutment, the concrete roadway resting on a fill held in place by wingwalls, the east one being on a curve. Following this there are ten beam spans each 32 feet long. This brings the structure to the north bank of the river. From this point a 142.5-foot deck span carries the bridge to the first river pier. Here the river channel starts and to meet the requirements of the War Department a 434-foot span of the through type was adopted. The clearance above water level is 75 feet. Two 199.5-foot deck spans and one 75-foot deck plate-girder span bring the bridge to the south bank of the river at Vandalia. Two 36-foot beam spans and ten 32-foot beam spans on the south end complete the superstructure, the remainder of the bridge being on an 81-foot filled abutment. The grade at this end of the bridge is 5.5 percent.

**Design Loads.** In the designing of this bridge the heaviest loading now recognized by highway bridge engineers was used, namely the so-called H-20 loading, which consists of a series of 20-ton trucks. These trucks are assumed to cover the bridge from end to end in four lanes, each lane being 10 feet in width. The trucks have a wheel base of 14 feet and a gauge of 6 feet. The assumed spacing of trucks center to center in a lane is 44 feet. On account of the improbability of any one span being loaded at one time with the full four lines of trucks of maximum weight, the loads were reduced 22 percent. However, the bridge has such a factor of safety that even with full loading the structure would be amply safe. The basic sidewalk load is 100 pounds per square foot, this value being decreased somewhat where the load is distributed over a considerable area, on the theory of improbability of full load ever being distributed over large areas simultaneously. Highway loads have increased very rapidly in recent years and will no doubt continue to increase, but it is believed that we have adopted values for this bridge that will take care of the growth for a great many years to come.

**Materials.** We are specifying special alloy silicon steel in the chord members of the 434-foot trusses. This represents an advance in the art of bridge construction as structural silicon steel is much stronger

than structural carbon steel and is being used more and more for large and monumental bridges. We specify that the ultimate tensile strength shall be between 80,000 and 95,000 pounds per square inch, with a yield point of not less than 45,000 pounds per square inch. The required ductility is obtained by specifying a minimum reduction of area in the test specimen of not less than 30 percent and a percentage elongation in 8 inches of not less than 1,500,000 divided by the unit tensile strength. Certain bend tests are also required.

For members that do not carry extremely heavy stresses carbon steel of structural grade is specified. This material has a tensile strength between 55,000 and 65,000 pounds per square inch, with a yield point of not less than one-half the ultimate strength and at least 30,000 pounds per square inch. Necessary ductility is assured by certain elongation and bend requirements.

In structural work steel must meet two basic requirements; (1) it must have the necessary strength, and (2) it must be ductile and tough. In the matter of strength there are two points that are of interest, the yield point and the ultimate strength. In making a tensile test of a piece of steel it will be found that if the specimen is loaded beyond a certain figure—much less than the breaking load—when the load is removed the specimen will not return to its original dimensions but takes on a permanent set. This point at which steel ceases to be perfectly elastic is called the yield point and is the limiting strength that the structural engineer can utilize. Any stress beyond this point will result in such distortion that failure quickly follows. Hence although we speak of steel having an ultimate strength of 60,000 pounds per square inch for example, its real strength in a structure is only about half this.

Much work is now being done by engineers and metallurgists seeking to get steel of higher yield points without necessarily higher ultimate strength, but with the ductility of present steels.

Ductility is necessary in structural steel to withstand the shock of cold punching of holes, cold bending of metal, and impact stresses developed during fabrication, erection and service. In general, ductility is obtained only at the expense of strength and vice versa. However, in alloy steels we can get both to a high degree.

All the steel used in this bridge will be specially rolled for the job and both chemical and mechanical tests will be made on every melt to safeguard the quality of every piece of metal used. A bridge is like a chain, the strength of the whole is no higher than the strength of the weakest element. Every member stands separate and independent of every other member and must be amply strong to carry its own share of the load.

For many years, in making concrete arbitrary proportions were used, as for example, 1 part of cement to 2 parts of sand to 4 parts of

gravel or crushed stone. It was thought that the strength of the concrete depended primarily on the amount of cement. As a result of exhaustive experiments by the Portland Cement Association embracing over a hundred thousand tests we know that the amount of water used in mixing the cement has even more influence than the cement content. For this reason we now specify concrete by water content, rather than by cement content. On this job for piers and abutments we call for a concrete containing not over 7 gallons of water per sack of cement, while for the floor of the bridge the water content is not to exceed 6 gallons per sack of cement. These values correspond approximately to 1-2½-5 and 1-2-4 concrete and should result in concrete strengths of not less than 2,000 and 2,500 pounds per square inch, respectively. Samples of concrete in the form of cylinders 6 inches in diameter and one foot high are made daily for testing at the age of 28-days as a check on the quality of the concrete work.

**Floor Construction.** The floor of this bridge has been designed to develop stiffness to a maximum degree as well as adequate strength. An asphaltic surface will be placed on the roadway to give easy riding qualities. The concrete of the roadway will have a thickness of 8 inches and will rest on stringers spaced 5 feet centers and running parallel with the trusses. All stringers are riveted into the webs of the floor beams and all floor beams are riveted into columns, plate girders and trusses. Such arrangement makes for stiffness and strength. Sidewalk concrete will be 5 inches thick.

The curbs will be 10½ inches high to prevent as far as possible vehicles out of control from mounting the sidewalks. A greater height would be desirable from a safety standpoint but is not advisable because of the danger of the running board of automobiles getting caught on the curb.

The roadway is given ample crown and a generous number of drain holes are provided to take off rain water from the floor as fast as it falls. We have all had experiences with the improperly drained floor where every automobile throws a spray of mud and water against people walking on the sidewalks. At all expansion joints along the floor heavy expansion dams are provided and it is believed the familiar rattle of most bridges at expansion joints when vehicles pass over the joints will be absent on this structure.

**Inspection.** No matter how skilfully and well a design is made and specifications are drawn, unless every element of construction is carried out in strict accordance with the design a first-class job will not result. Bearing in mind that a weakness anywhere in the bridge is a potential source of failure and that no amount of reserve strength at one point will help a weak point elsewhere, it is evident that only with the closest inspection of every part of the construction work can the engineer accept the responsibility for the resulting structure.

All piles are inspected for size, soundness of material, strength, form and amount of creosote carried. When driven they are tested for bearing capacity.

All foundations consisting of rock are carefully inspected to see that no cracks or fissures exist and that the bearing capacity is satisfactory.

In concrete work, the cement, sand and gravel are each tested. For example, cement is tested for strength, size of particles, specific gravity, soundness, etc. Sand and gravel are tested for character of particles, gradation of size, etc. After these are combined together in proper proportions and water added, samples of the resulting concrete are made in the form of cylinders and tested in compression. The amount of water used, the length of time that the concrete is mixed, the method of transporting it, the placing of it in the forms, and the curing of the same, all these are elements that vitally affect the strength and permanency of the concrete.

As stated elsewhere, all steel used is specially rolled for the job in order that the quality may be known. Chemical tests are made to determine the amount of sulphur, phosphorous and other elements present, for they must be kept at a low figure. Mechanical tests are made for tensile strength and bending. These tests are of such a searching character that it is almost impossible for poor steel to get by the inspector. After being delivered from the rolling mills the steel is taken to the fabricating plant, where it is cut to sizes, holes punched, material assembled, rivets driven, material painted, etc.; all these operations being under the watchful eye of an expert. Again when erection starts the inspector checks up each member as it goes into place, testing every rivet driven, measuring the sizes of the members, watching for poor fits and other things too numerous to mention. Good work results only from eternal vigilance on the part of the inspector and fortunate is the engineer who knows his structure is to receive proper inspection.

**Design Features.** Many novel design features have been used such as higher unit stresses, the use of long panels, the use of structural silicon steel, riveted construction throughout, a special type of truss for the 434-foot span and dust guards for all roller shoes.

A unit design stress of 16,000 pounds per square inch in tension has long been the standard in bridge construction. It is believed by many engineers that this value is unduly conservative and values of 18,000 and even 20,000 are now justified. The arguments for these higher values are many and varied; the steel is stronger than it formerly was, it is more uniform and reliable, designs are more carefully and scientifically made to include the effects of all loads, details are much better worked out, shop work is superior and under much better control, erection work is on a more scientific basis and under superior inspection. Most steel building work is now designed on the basis of 18,000

pounds. I believe the arguments for higher stresses are sound and we used 18,000 for the basic unit on this bridge for all structural carbon steel. For structural silicon steel we used a value of 24,000 pounds per square inch for tension. Since the structural carbon steel has a yield point of not less than 30,000 pounds per square inch we have, using a working stress of 18,000 pounds per square inch, a factor of safety of at least  $1\frac{2}{3}$ . In other words to fail the structure all loads, both live and dead, would have to increase 67 percent over those used in our design. The minimum factor for safety for the silicon steel is 1.87, in other words loads would have to increase nearly double to cause failure.

Panel lengths as high as 36 feet are used in our design, whereas the usual panel length for highway bridges is about 20 feet. The use of long panels lessens the amount of shop work and makes erection work more economical as well as simplifying details. It also makes a better looking structure. The use of long panels is made possible by the new series of beams now being rolled by the Carnegie Steel Company and the Bethlehem Steel Company. These beams not only run heavier than the old series but are much more economical of material; that is, the load carrying capacity per unit of weight is much higher. The heaviest beam formerly rolled by the Carnegie Steel Company was 24 inches deep, weighing 120 pounds per foot and had a load capacity of 251 units. Now the heaviest beam is 30 inches deep, weighs 240 pounds per foot and has a load carrying capacity of 738 units. In other words, with a beam twice as heavy we have a strength increase of three fold. The heaviest Bethlehem section now rolled has a depth of  $36\frac{1}{4}$  inches, weighs 260 pounds per foot and has a load carrying capacity of 949.5 units. With such heavy and strong beams available the field for economical structural design on large bridges is immeasurably broadened.

The use of the Warren type of truss with curved upper chord for the channel span represents a marked departure from current practice. The more usual type is the Pennsylvania truss. The advantages of the Warren type is the elimination to a large extent of secondary stresses, the smaller amount of shop and erection work and the more pleasing appearance of the structure. The main disadvantage is the greater tonnage involved. However the increased cost due to larger tonnage is partially offset by the lessened cost of fabrication and erection. The elimination of subdivided panels is largely due to the economical use of longer panels explained above.

The use of structural silicon steel for the chord members of the channel span is commented on elsewhere in this paper. The cost in cents per pound of silicon steel is slightly higher than that of carbon steel but the saving in tonnage due to higher unit stresses used results in a decided total saving. However, for other parts of the bridge where the stresses are not so high, this is not true. The maximum stress in

the chords is 2,800,000 pounds requiring a sectional area of 140 square inches. This would have been increased to 197 square inches had carbon steel been used.

All connections throughout this bridge are riveted. Some engineers still use pin-connected joints for long spans but the tendency is more and more toward the use of riveted connections. The main advantage of riveted construction is the greater stiffness resulting. Pins sometimes show considerable wear and occasionally have to be replaced. However, this is not so often required for highway bridges as for railroad bridges. The two main advantages of pin connections are the freedom from secondary stresses and the somewhat lower cost. However, most engineers agree that the advantages of riveted construction outweigh the disadvantages.

One end of all spans of any considerable length must be placed on rollers or rockers to allow free movement of the steel under temperature changes. If this is not done failure soon results. Much trouble is usually experienced by roller nests becoming filled with dirt and rusting so that eventually a free movement is no longer possible. On this bridge we are enclosing all roller nests by dust guards, and we hope that with occasional maintenance oiling and greasing we will avoid the above mentioned trouble so often encountered.

Economy has been obtained in pier design by using the dumb-bell type, instead of solid piers. Here, two vertical shafts are used, one under each truss bearing, and these shafts are connected by a web to give the necessary stiffness. This type of construction is especially economical for high piers, such as are used in this bridge, the height reaching 85 feet.

**Ornamentation.** In designing this structure attention has been given to making the lines of the bridge as attractive as possible, consistent with strength and economy. All changes in grade are effected by vertical curves, which not only enhance the beauty of the structure but also make for easy riding qualities.

All spans other than the channel one are deck structures, that is, the roadway is along the upper chord of the trusses. This affords a clear and unobstructed view up and down the river. The channel span is of the through type, the floor being along the bottom of the truss, in order to give the necessary vertical clearance for river traffic. Particular attention has been given to making the lines of this channel span as pleasing as possible as it will stand out rather prominently either from on or off the bridge.

The outside of the wingwalls of the abutments and the concrete hand rails on these wings have many ornamental features and will give a pleasing appearance to the structure as one approaches the bridge. The railing on the bridge proper is composed of cast-iron posts and steel sections. This railing is designed to harmonize with the rest

of the bridge and add ornamentation. Ornamental light standards will be used with lights along each sidewalk spaced about 110 feet. The railing and light standards will be painted a silver color, and the rest of the bridge will be painted a light gray. Light colors are especially desirable from an architectural standpoint in heavy construction work. For light structures often times a dark color paint gives a better appearance.

**Quantities and Cost.** The river piers will rest in solid rock while the land piers and abutments will have foundations of creosoted timber piling. The substructure work which includes all piers and abutment construction, will consist of 2750 cubic yards of dry excavation, 2355 cubic yards of wet excavation, 77 cubic yards of rock excavation, 7458 cubic yards of concrete, 428 feet of concrete railing, 149,500 pounds of reinforcing bars and 20,650 feet of creosoted piling. The contract price for this work is \$176,553.00.

The superstructure of the bridge includes 5,214,000 pounds of structural steel, 751,000 pounds of silicon steel, 67,000 pounds of cast steel, 277,550 pounds of reinforcing bars, 51,000 pounds of wire fabric, 3550 feet of metal railing, and 5325 pounds of curb guard. The contract price for this work is \$469,100.00.

Other work to be done includes an asphalt wearing surface, filling and paving for the approaches and a lighting system. These items, when added to the substructure and the superstructure contract costs, will make a total of approximately \$700,000.00. To this will be added about \$50,000 expended for right-of-way, making the total cost about \$750,000. Adding to this figure the \$350,000 paid for the Kanawha City bridge the total is \$1,100,000 or \$150,000 less than was made available by the bond issue.

In making up the estimate for the bond issue, an item of \$40,000 was included for engineering costs. As the state road commission later agreed to take care of all engineering costs this item does not appear in the above costs, but it should appear in placing a value on the west end bridge.

On the basis of a cost of \$700,000 for the actual bridge, the cost per square foot of roadway, giving one-half weight to the sidewalks, and considering the length of the bridge as 1770 feet, is \$8.25. This is a low figure for such a structure as this and is due largely to low prices now prevailing in the construction field. The engineers connected with the design of this bridge have tried to prepare a design which will meet all traffic demands as to strength and durability and yet keep the cost down to the lowest point consistent with conservative engineering.

This bridge is being built by the County Court of Kanawha County, W. H. O'Dell president, H. A. Walker, J. C. Blackwood and Omer Given, members. C. M. Ross is the county engineer, E. S. Bock the attorney for the county and R. N. Moulton, the county clerk. The

county court is being assisted by the citizens committee consisting of Carl Scholz, chairman, C. E. Krebs, E. H. Jones, John Price, Dr. R. H. Dunn, and Peter Silman.

The state road commission, C. P. Fortney, chairman, C. E. McCoy and Harvey Marsh, members, has charge of all engineering work. The writer designed the bridge, the design being checked and drawings made under the direction of L. L. Jemison, bridge engineer for the commission. Surveys were made under the direction of H. R. Anderson, division engineer, who is also in charge of construction engineering, the writer assisting him as supervising engineer.

## EFFECT OF TEMPERATURE ON SHEAR MODULUS

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(Abstract)

Work has been done on Young's Modulus which shows its variation with the temperature. A. L. Kimball (Phy. Rev. 26, p. 121, 1925) measured the change in iron over a range of 400°C. starting from room temperature and found a decrease in the modulus of the order of magnitude of 16%. A. Mallock (Proc. Roy. Soc. A 95, p. 429, 1919) compared the ratio of the modulus of some 15 different substances at the temperature of liquid air and room temperature. When these ratios were plotted against the melting point some regularity could be noted.

In the study of the change in the shear modulus, similar results to those obtained on Young's Modulus are to be expected as the nature of the molecular forces are probably the same in both cases, the method employed consisted of noting the period of vibration of a torsional pendulum the supporting wire of which hangs along the axis of a long cylindrical furnace and thus being subject to various temperatures. The inertia disk vibrated just below the end of the furnace and was under the same conditions at all times. The method also has this important advantage that it allows the damping to be measured by means of the logarithmic decrement. Thus instead of saying that internal friction is negligible it enables the exact specification of just how negligible.

The results obtained on the Shear Modulus of steel for a range of temperature from that of the room to 370°C. showed a 16% decrease in the shear modulus, with a somewhat abrupt change setting in at about 275°C.

The damping, while negligible so far as the period of vibration is concerned, showed a gradual increase to 275° and from there on a very rapid rise such that if continued at the same rate to 450°C. the internal friction would have an appreciable effect on the period of vibration.

## THE EFFECT OF WEATHER CONDITIONS ON RADIO RECEPTION

By R. C. COLWELL, R. G. OWENS and W. M. DOVE,  
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(Abstract)

The early observations of Marconi have shown that the day signal from any given station remains fairly constant while the night signal fluctuates considerably, but its average intensity is above that of the day signal. This is probably true over great distances, say 500 to 1000 miles, but we have found by observation upon KDKA at Morgantown, a distance of 60 miles, that the night signal may be equal to greater than or lower than the day signal. Records have been taken over a period of three years but the report of this afternoon refers only to the intensity curves for February and March, 1929. We had noticed before that a rising curve after nightfall indicates cloudy or stormy weather, while a falling curve is likely to be followed by clearing weather. Using this method we have been able to forecast weather conditions at Morgantown with considerable accuracy. The curves shown will indicate our method. The weather of March 25 was warm and cloudy. The curve taken that night rose for awhile and then fell. This was taken to mean that the cloudy weather would continue next morning with clearing weather in the afternoon. The weather Tuesday, March 26, showed showers in the morning with the afternoon clear. We marked ourselves "Partly right."

March 27, Wednesday. Weather clear, broken clouds, cloudy in the evening. The curve rises and falls. Hence continued cloudiness with showers. Very cloudy but no rain. Partly right.

March 28, 1929. Heavy clouds all day. The curve was low and rose again. Hence the prediction—continued clouds and sunshine. Weather on Friday—sunshine in morning, clouds all afternoon.

Twenty-one curves for February thus interpreted gave 71% exactly correct and 90% nearly correct. Only one out of the twenty-one was completely wrong. Twenty-six curves in March gave 88% nearly correct with three entirely wrong. This degree of accuracy compares very favorably with other methods of forecasting with the limitation that it is purely local.

## SOME EFFECTS OF COLOR AND ILLUMINATION

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When a person looks through an open door he quite often sees the wall back of the door, as the door, making him feel at first glance that the door is closed and of the same color as the wall. Luckiesh in his book "Visual Illusions and Their Applications," suggests an apparatus for using the above effect to compare surfaces of different intensities and color.

Following this suggestion the writer built a box 27"x18"x18" with an opening ten inches square cut in one end. About fifteen inches from this end is a metal diaphragm with an opening four inches square in its center. At the far end is another metal plate which covers the entire end of the box. Both pieces of metal are painted white. At two sides of the front opening are placed a row of three light sockets with baffles placed over them so that the light from them will illuminate the center diaphragm but will not illuminate the visible part of the rear metal. Just back of the center diaphragm are six more light sockets which illuminate the rear end but with baffles so that their light will not enter the hole in the diaphragm except by reflection from the back surface.

What the writer had in mind was to test the effects of illuminating the surfaces with lights of various colors and different intensities. However due to lack of adequate current carrying rheostats the latter point was largely abandoned for the present. The effects of a few colors were tested with the results given below:

No.	Back illuminated with bulb colored	Front illuminated with bulb colored	Back color apparent	Front color apparent
1	Yellow	Unilluminated	pale orange	grayish
2	Yellow	white	reddish orange	white
3	Yellow	yellow	pale yellow	pale orange
4	Yellow	blue	orange	light blue
5	Yellow	red	yellow	light red
6	Blue	unilluminated	blue	dark
7	Blue	white	dark blue	white
8	Blue	yellow	blue	yellow
9	Blue	blue	blue	light blue
10	Blue	red	dark blue	orange
11	Red	unilluminated	pink	dark
12	Red	white	red	white
13	Red	yellow	light red	yellow
14	Red	blue	pink	dark blue

15 Red	red	yellow	orange
16 White	unilluminated	white	gray
17 White	white	white	light gray
18 White	yellow	white	orange almost yellow
19 White	blue	white	blue
20 White	red	white	light red
21 Yellow & blue	unilluminated	yellow	dark
22 Yellow & blue	white	pink	white
23 Yellow & blue	blue	yellow	blue
24 Yellow & blue	red	deep yellow	red
25 Red & yellow	unilluminated	yellow	dark
26 Red & yellow	white	orange	white
27 Red & yellow	blue	orange yellow	blue
28 Red & yellow	red	yellow	pink
29 Red & blue	unilluminated	pink	dark
30 Red & blue	White	red	white
31 Red & blue	blue	pink	light blue
32 Red & blue	red	faint pink	light red
33 Red, yellow, blue	unilluminated	yellow	dark
34 Red, yellow, blue	white	orange	white
35 Red, yellow, blue	blue	yellow	light blue
36 Red, yellow, blue	red	light yellow	light red

From the view point of a psychologist these readings were undoubtedly taken incorrectly for in each the writer knew the color of the bulb being used to illuminate the surfaces. However in several cases the color was not what would naturally be expected and so the writer does not feel that this effected the observations to any noticeable degree. It does seem probable that some rather interesting information could be obtained by having the surfaces observed by individuals who did not know the color of the bulb being used.

The above table gives merely the observations of color while in a few cases there were other interesting effects which should be brought out. In No. 5 the colors of the surfaces are given as of the same color as the bulbs but in fact there was a decidedly noticeable difference in shade. In No. 6 the back seemed to stand in front of the center diaphragm.

Number 7 was possibly the most interesting one of the entire set for the back surface appeared to have a different color near the edges than at the center. The edges next to the white surface were an extremely dark blue, almost black. This faded gradually toward the center into a light blue of about the same color as the bulb itself. This is probably due to the contrast between the dark surface and white but it was not noticeable in any other case.

In No. 9 both surfaces were illuminated with blue bulbs of the same intensity but the back surface appeared to stand out prominently with a decided blue as though it were more intensely illuminated than the front. Cutting the back illumination to one-half seemed to cause the two surfaces to merge together with the same color. The same effect was noticed when both surfaces were red, but to a somewhat smaller degree.

When the back was colored blue and the front illuminated with red as in No. 10 the back surface seemed to have been moved away from the front so that it gave one the feeling that it was farther away than it actually was. When the illuminating colors were reversed the two surfaces appeared to be about equally distant from the observer.

An interesting thing that is present throughout the observations is the lack of agreement between the color of the bulb being used and the color of the surface illuminated. It would seem that the neighboring colors affect the color of a surface to a considerable extent. This is probably due to contrast.

The number of observations made are not sufficient to enable one to draw any definite conclusions except as they confirm other observations. If a large number of observations could be made by a number of people there might be some definite conclusions drawn, particularly as to the effect of adjacent colored surfaces upon each other.

## ENERGY LEVELS OF THE PLATINUM ATOM

By PAUL J. OVREBO,

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Until 1913 when Nils Bohr, the brilliant Danish physicist, advanced the fundamental assumptions which laid the basis for his atomic model, there had been no way of connecting the spectral lines of an element, which were known to come from the atom, with any atomic model. He pictured the atom as a system not unlike our solar system, in which the planets revolve about the sun in definite, discrete orbits. He conceived a central positive charge as the nucleus of the atom. He then conceived of the negatively charged electrons of the atom as rotating about the central nucleus like the earth rotates about the sun. However, instead of keeping the electrons in one orbit, after the manner of the earth, he allowed them to jump from one orbit to another under certain conditions. These electron jumps were called transitions. As long as an electron stayed in an orbit, even though rotating continuously, he assumed that no energy was given off. However if an electron were to jump from an inner orbit to an outer orbit energy would be absorbed, while if an electron jumped from an outer orbit to an inner orbit, energy would be emitted. This energy emitted when an electron jumps from an outer orbit to an inner orbit may come to us as ordinary light, or if the energy is sufficient as X-Rays.

In the case of the hydrogen atom we have one positive charge as the nucleus and one negatively charged electron rotating about it. In the case of the platinum atom which is the subject of study in this paper, there are 78 electrons rotating in different orbits about the nucleus, when we use the picture of the Bohr atom. The atomic number, that is the number of electrons in an atom, has been determined for each element by X-Rays. Each of these orbits or levels may be expressed in terms of wavenumbers, where wavenumber is the reciprocal of

the wavelength,  $n = \frac{1}{\lambda^*}$ . When one of these electrons jump to an inner level we get a spectrum line of a certain wavelength. The wavelengths of 844 such spectrum lines for platinum have been measured by Kayser, Exner and W. F. Meggers of the Bureau of Standards. Each one of these wavelengths have been converted into wavenumbers.

In 1900 C. P. Snyder reported a list of energy levels. In 1926 J. C. McClellan and A. B. McLay found a few more. In 1927 A. C. Hausmann added two more intermediate levels, which brought the total number of levels known for platinum to 72. In 1928 the author added 68 new levels. In this present paper it is possible to report the addition of 58 new levels, which have been found since October 1928.

There are three groups of levels, low, intermediate and high. The

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\* $\lambda$  is in terms of centimeters.

low levels indicate the inner ones and the high levels mean the outer ones, while the intermediate levels lie between the low and high levels. An electron or electrons may jump from an intermediate to a low level, or from a high to an intermediate level to form a spectrum line. The numerical difference of the wave number of the levels which enter

High	59,908.1	
		27,687.3
Intermediate	32,220.8	
		21,108.4
Low	11,112.4	

into a transition gives the wave number of the spectrum line, which has already been measured experimentally. For example the intermediate level 32,220.8 combines with the low level 11,112.4 to form the spectrum line 21,108.4. The experimental determination of the wavelength expressed in wave numbers is 21,108.58. This arithmetical means of describing spectrum lines as the difference of the wave numbers of energy levels, or as frequently called terms, is one of the most undisputed facts of the atom. It is also independent of any atom model.

Since the numerical values of the levels in the platinum atom runs from 0 to 68,000.0 wave numbers and since the agreement of the combinations agree with the measured values of the spectral lines within .4 wavenumbers, it is difficult to explain away the validity of these terms and their combinations by means of probability. Not any of the levels with the exception of one, enters into less than three combinations, while some enter into as many as twelve combinations. Thus these new energy levels appear to be true terms, which may be taken as the orbits in which the electrons rotate, if we think of a Bohr atom model.

The method used in finding these new levels is to take the levels which are already known together with the spectrum lines which have as yet not been described by combinations. Thus in the diagram the old known low levels are each added to the undescribed spectrum lines to give a large number of hypothetical levels. If one of these hypotheti-

cal levels appears a number of times in this scheme, within the limit set, it is taken as a new intermediate level. It is now taken and combined with all the low levels and intermediate levels in the search of undescribed spectrum lines. All the numerical work is very laborious, but it must yield the spectrum lines. Most of the new levels have been classified by means of combinations and the Selection Principle.

		$v_1$	$v_2$	$v_3$	$v_4$ etc.	Underscribed
Old	$v_a$	×	×	×	48,156.6	Spectrum Lines
Known	$v_b$	×	×	×	×	
Low	$v_c$	×	×	×	×	
Levels	$v_d$	×	×	×	×	
	$v_e$	×	48,156.4	×	×	
	$v_f$	×	×	×	×	

The numbers marked × give prospective levels. But those which agree numerically are the ones used.

COMPARATIVE RESULTS OF DIFFERENT METHODS  
OF SCORING TEST PAPERS

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When one surveys the field of standardized tests he is likely to be impressed with the appearance of a considerable variety of methods of scoring performances, and perhaps to wonder whether there is any unique virtue in the technic peculiar to any particular test. It is the aim of this paper to canvass the situation with a view to discover the relations of these various procedures to each other.

The most common types of scoring procedure that may be isolated are the following: (1) count-of-total-performance or count-of-number-exercises-correctly-performed; (2) cumulative or summation method; (3) value-of-total-performance; (4) value-of-most-difficult-exercise. These four methods will be illustrated by citation of standardized tests which employ them, in the hope of making the somewhat tangled situation as regards scoring methods appear a bit simpler. In the illustrations no attempt will be made to provide complete and detailed descriptions, but only to make essential statements.

The first named method, count-of-total-performance, is well illustrated by Monroe's revised silent reading test; for rate score one counts exact number of words read per unit of time; for comprehension score one counts number of paragraphs correctly handled. One could readily identify this with the cumulative method by assuming that the value of each exercise in the test is unity, and that the total score is determined by summing the values of all the exercises correctly performed. This method requires no further exposition.

The cumulative or summation method is the one in most common use; one simply assigns values to the several test exercises and adds together the values of those correctly performed; the allotted values may or may not all be equal to one another; one may introduce the use of partial credits for partially correct performances on some exercises without departing from the essence of the method. Because this is the commonly used procedure it will be employed as the point of reference in the discussion of other procedures. There is no aspect of this common method that particularly needs discussion save the effect upon scores when values assigned to the several test exercises are not of uniform magnitude.

When weighted values are assigned to test exercises, weights may be determined upon the basis of relative importance, time consumption or relative difficulty. The original Monroe silent reading test is a good illustration of the use of weighted values for the test exercises.

We can determine effect of use of weighted values only when we score test performances with uniform values for exercises and also with

weighted values, and observe the departures in the second case from the order established by the use of uniform values or calculate the correlation between the two series of scores.

The Trabue completion-test language scales may be used as an illustration of the application to standardized tests of the common cumulative method of scoring. For proper treatment of each exercise a credit of two points is allowed; for slightly imperfect treatment a single point is allowed; the points earned on the several exercises are then summed to make the score.

Trabue completion-test language scale B was given to 793 eighth grade pupils. Papers were scored according to the procedure recommended by Trabue. For each sentence correctly completed two points were allowed; for each sentence completed with minor imperfection a credit of one point was allowed; the Trabue key was the basis of decision in every case; the score for each paper was obtained by adding together the points earned on the several exercises; this provided a series of scores determined by the cumulative method with uniform values for the test items. Papers were then re-scored, exact difficulty values of the exercises being used in place of uniform values, half of the difficulty value being allowed in case of the minor imperfections in performances. The values employed were those given by Trabue, ranging from .96 to 10.76, the interval being approximately one point throughout, although not absolutely uniform.

To illustrate the possible changes in relative scores we may cite the case of two pupils who were members of the same class. On the first scoring each pupil received a score of 8 points; on the re-scoring one was given a score of 10.14 and the other a score of 16.64. On first thought, one is inclined to anticipate a considerable shaking up in relative ranking of the members of a group taking this test, when the weighted values are substituted for the uniform values of exercises. On second consideration, we recall the general rule that the effect of any component in a composite score does not depend upon the magnitude of the allowance for that component but upon the dispersion of performances upon it. Effect of using weighted values will depend upon prevalence of lapses on relatively easy exercises and recoveries in the more difficult portions of the test. Since pronounced degree of lapsing is not common, it follows that, on a priori grounds, we should not anticipate any radical effect to result from substituting weighted values for uniform values of exercises.

What actually happened we may see in results from a single class of 28 members. If we arrange the scores in descending order as they were obtained from the scoring with uniform values for exercises, and then put beside each score the score obtained on the same paper when weighted values are used, we find that we have still an arrangement practically in descending order, only two scores out of 28 being out of

order. The use of weighted scores gave to one pupil a position above four others who stood above him on first scoring; in the other case the use of weighted values stepped the pupil up one place.

To test further the effect of use of difficult values for the several exercises in place of uniform values we may consider class results from the re-scoring of 451 papers written by 15 eighth grade classes. The median of each class was determined from the original scores. The median score of each class was again determined after the weighted values were substituted for the uniform values of exercises. The first median scores were arranged in descending order and the median scores of the second scoring were placed in parallel column. The second column of medians retained the descending order aspect except for two cases out of 15. The use of the weighted values sent the media score of one class above another class which had been just ahead of it when uniform values were used; in the other instance, the class concerned was stepped up two places.

Judging from this and other experiments, it is a fair conclusion that the results obtained by the use of test item values weighted according to difficulty or importance or time consumption will not materially differ from general results obtained by the use of uniform values. The simpler process of using uniform values for test exercises is therefore to be recommended.

We come now to a consideration of the third method mentioned above, using as a score the value-of-total-performance. McCall advocates abandonment of the use of different values for the several exercises of a scaled test, but favors the determination of the score from the total performance of the pupil, a difficulty value being allowed for the total performance. The difficulty of doing any particular number of exercises is, of course, to be determined from the percent of a typical group who can achieve that performance.

The number of questions or exercises of test elements that any subject of a test can perform correctly is here spoken of as his total performance. That is, the total performance is determined by a simple count of correct responses. The first step in this method is therefore identical with the first method listed above. McCall's idea is that the difficulty of this total performance varies with the number of exercises, and that the difficulty value of his total performance should stand as the subject's score on the test. Observe that it is not stated that difficulty is proportional to the number of exercises correctly performed.

Suppose that we take the results already referred to as obtained from the giving of the Trabue completion-test language scale to 793 eighth grade pupils, and that from these results we determine the difficulty values of the several possible performances. When we do so we find a fairly uniform step in difficulty from performance to performance. In other words, the difficulty value of any total perform-

ance may be thought of as an initial or basic amount plus a multiple of a certain increment.

Let  $K$  represent the difficulty or scale value of doing a single exercise in the test, and  $K+M$  the value of doing two exercises; we find that  $K+2M$  is the difficulty value of a performance of three exercises, etc. The series of difficulty values for the possible performances is then  $K, K+M, K+2M, K+3M, K+4M, \dots, K+(N-1)M$ , where  $N$  represents the number of exercises in the test. If, from each item in this series, we deduct the constant  $K-M$ , then we have left a series reading thus:  $M, 2M, 3M, 4M, \dots, NM$ . In other words, the series of difficulty values in this method correlates perfectly with scores obtained by the cumulative method with uniform value for exercises when  $M$  is that value.

The preceding statement is entirely true with respect to any group of subjects, such as a grade group or an age group. When we come to consider the case of different age or grade groups we find a different situation facing us. The difficulty values for the series of total performances for a fifth grade will differ from the series of difficulty values for the several total performances in the sixth grade in respect that the constant basic element is different for the different grades. In other words, the starting point of credit, or the zero point, is not the same for different groups of subjects. This is the peculiar characteristic of the value-of-total-performance method of scoring test papers. It can, of course, only be used on standardized material, or it can only be used on unstandardized material by going through a process of determining of values which is virtually the same as the process of standardizing values. There may be advantages in having a different zero point for different groups of subjects, but the fact remains that so long as we are considering any one group the scores present exactly the same picture of the relative performances of the members of the group as do the scores obtained by the commonly used cumulative method.

For an illustration of this method we may go to the Burgess test in silent reading. Twenty paragraphs are provided; a time limit is imposed; a count of correct responses is made; the value of any total performance is at once read from a table. The value of any total performance depends upon the grade to which the pupil belongs. The value of 50 appears to have been given arbitrarily to the median performance of each grade group tested in the standardization process. Except at the very extreme performances the uniform step in difficulty from performance to performance has been given a value of 6 points. Consequently the zero point is not placed at the same total performance for any two grades.

The peculiar advantage of this method consists in the fact that a mark of, let us say, 90, is as easily earned by a pupil of one grade as by a pupil of another grade. The persistent fact is that, within any

group, results on this method march consistently with results by the cumulative method.

Finally, we must consider the fourth method listed above, the use of value-of-most-difficult-exercise as score. McCall has made the following criticism of this method: "To call a pupil's score the scale value of the most difficult test element done correctly is subject to the objection that pupils are unable frequently to do correctly test elements of less scale value. Depending as it does upon a single test element, the score would also be rather unreliable." McCall's first objection to the method is so easily obviated by a slight correction, viz., a set-back for exercises not successfully performed, that it need not be taken too seriously.

Probably the best example that we may call to attention is the Buckingham scale in arithmetic. Without trying to state all of the facts characteristic of this scale we may note that there is a series of thirty problems for which difficulty values are provided. Essentially there is a uniform step in difficulty from problem to problem throughout the series or, at least, for our purposes, we may speak as though there were. Buckingham proposes the simplest possible type of scoring procedure. From the value of the most difficult exercises correctly performed, one subtracts the value of the uniform difficulty step for each exercise not correctly performed. Let us suppose that a pupil performs correctly six exercises, misses on one, performs correctly three more, misses two, succeeds on another, and then breaks down completely. The pupil has performed correctly the thirteenth exercise and to determine his score we take the value of the thirteenth exercise, deducting from it three times the uniform difficulty step because the pupil has missed on three exercises. The pupil's final score then is the value of the tenth exercise, the pupil having done correctly ten exercises. Since there is a uniform difficulty step in the series of problems, the value of this tenth exercise is really the value of the first exercise plus nine times the increment of difficulty. Let  $K$  be the value of the first exercise, and  $M$  be the scale step from exercise to exercise. Then the series of values of the problem is  $K, K+M, K+2M, K+3M, \dots, K+(N-1)M$ , where  $N$  represents the whole number of exercises in the test. The correction for error is always a multiple of  $M$ ; consequently the scores after correction are always found in the series just stated.

Suppose that from each item in this series of exercise values we should subtract  $K-M$ ; then our series becomes  $M, 2M, 3M$ , etc., which correlates perfectly with the series  $K, K+M, K+2M, K+3M$ , etc. The simple series resulting from this subtraction might just as well be used as the other series of problem values.

Suppose, on the other hand, that we were to use  $M$  as the uniform value of the several exercises, regardless of the fact that they are not

of uniform difficulty, and apply the cumulative method of determining scores. Then the series of possible scores would be as follows: M for one correct, 2M for two corrects, 3M for three corrects, etc. It is apparent then that the method of using as score the scale value of the most difficult exercise done, with correction for errors on the easier exercises, is essentially the same as the cumulative method in common use. That being the case, McCall's second objection to the method disappears. His criticism is valid only in case no correction for errors is made.

A more complicated technique is used by VanWagenen and his associates. The particular test in mind in the following statement is a Posey-VanWagenen geography scale. The essentials of the scoring system are as follows: the test is divided into three divisions, and the exercises are scaled as to difficulty; one first finds in a table the uncorrected score for any number of corrects in the middle portion of the test; at this point it is apparently assumed that all of the exercises of the easiest third of the test have been correctly performed; one corrects this first score by adding an amount provided in another table, the amount of the correction depending upon the number of corrects in the most difficult third of the test; one then makes a second correction by subtracting an amount read from still another table, the deduction depending upon the number of errors in the easiest third of the test. The amounts to be added and subtracted are not directly proportional to the number of corrects in the difficult section or to the number of errors in the easiest division of the test. Some other factor is at work to determine the magnitude of the corrections.

Throughout the scale there is a uniform difficulty step of one point. One might expect that a pupil who does correctly one exercise in the third division would have one point added to his score; he is entitled to  $1\frac{1}{2}$  points; for two corrects, 3 points are added; for three corrects, 5 points are added; for four corrects, 7 points are added; for five corrects, 9 points are added; for six corrects in the most difficult third of the test, 12 points are added. It is unnecessary to carry that tale farther.

If one should do correctly all of the exercises of the first and second divisions of this test his score would be the scale value of the last problem in the second division, namely, 84. If one should do, in addition, one exercise in the third division, his score would be, not 85, as we might expect from the Buckingham procedure, but  $85\frac{1}{2}$  if one should do still another exercise from this most difficult portion of the test his score would be 87, not 86, etc. The probability of success on problems still more difficult than any that are included in the test is estimated from the actual performance on the third division, and an increment of score is allowed in proportion to that probability. Consequently, the more one earns on the third division exercises, the more

there is allowed for probable corrects in a hypothetical fourth division of the test. This unearned increment of score is allowed on the theory that the subject of a test has a right to be tested to the limit of his ability, and that, when one is deprived of the opportunity to display the last resource of his ability, he must be granted a reasonable increment of score according to his actual performances.

In similar manner it is discovered that the correction to be made for errors in the first division of the test seems to involve a fine or deduction based on the assumption that a test subject who makes errors on this section of the test would also make errors, although fewer of them, on a still easier portion of the test, were much easier portion provided.

We may say, then, that in this illustration the Buckingham procedure is applied, or would be applied if the test were completed by offering exercises so easy that no one could conceivably miss them, as well as exercises so difficult that no one could conceivably do them correctly.

The conclusion that one is entitled to reach is that the various scoring schemes employed in the standardized tests of this period, unique as they often seem to be, are generally capable of reduction to the cumulative form, or that the results obtained by them are fairly consistent with those obtained through the application of the cumulative method. In so far as results obtained by the invented methods do differ from those of the cumulative method, they are not convincingly more accurate or more just than those the time-honored procedure produces.

## OUR EVOLVING SOCIAL CONCEPTION OF SCHOOL

By H. T. McKINNEY,

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Too long the laity has thought of school as a static thing instead of the constantly changing institution that it is. School, like other institutions, lives and thrives in the degree that it supplies some felt need of the social group that affords it sustenance. A glance at the history of American education of about three centuries is sufficient to show this point. At one time the school existed solely to train certain individuals in the community in the mere rudiments of reading, writing and the like, because this conception of education satisfied the community's demand for a select few to be able to carry on written communication and do the simple arithmetical computations. Later, the demand was broader so as to prepare all the children of a settlement to read the Bible for themselves in accordance with the Protestant religious conception. At still another time, the school was the means of giving the individual "an education" which was regarded as a distinct advantage in an economic way. Education was the means of avoiding the necessity of "hard work." Finally we have evolved the conception of school as a social necessity. It is no longer merely a desirable thing in a community or an advantage to be shared for the few who are fortunate enough to attend, but it is a necessity. Our present order of society is unthinkable without the formal training afforded by the school. The purpose of this paper is to direct attention to some of the present day implications of this statement.

First, society is the final determiner of the school. Illustrations of this principle might be cited at length. We will name but three. Richard Mulcaster (1531-1611) wrote his treatise on education ("Positions") in which he outlined and set forth ideas that would have transformed the schools of his day into 20th century institutions advocating "education of all and for all" but this London Schoolmaster was ineffective because he was not sufficiently in step with the demands shared by the rank and file of the day. Thomas Jefferson also proposed an educational scheme that the educators of our day praise in the highest terms but his plan for a system of universal education headed up in a University, likewise did not meet success. Its author lived back in the social group that failed to mention education in the Federal Constitution. Had Jefferson lived in our day when there is a growing demand for a Secretary of Education in the president's cabinet, society would have dealt with his scheme quite differently. And, we may draw on school administration for a leader that shows the same point. In the last decade of the 19th century, Pueblo, Colorado, had Preston W. Search at the head of the schools of that city. In that period the leaders in the National Educational Association were decrying the lockstep in

the American schools. Various plans were proposed in Cambridge (Mass.), in Seattle (Wash.), in Denver (Colo.), and in other cities including Pueblo. To strengthen and give impetus to his endeavors Mr. Search wrote, "The Ideal School," a book of lasting merit. During his administration in Pueblo the scheme of promotion was carried out enthusiastically much as we read of the experimental school at Winnetka or at Dalton being received today. No one could say that the Pueblo Plan was not a decided improvement over the old plan of promotions any more than one could rightly say that Winnetka or Dalton is not more ideally correct in procedure. But what of the Pueblo Plan in 1920, just 30 years later? Talking to a late superintendent of the Pueblo schools, a year ago, the writer whose major interest in the field of administration is in the matter of proper promotions, asked, "Do you folks still make use of any part of the famous Pueblo Plan of Promotions?" Seeing that the question had gone afield, the questioner substituted the question, "Do you find any of the footsteps of P. W. Search?" This time the response was, "I believe there was an old man around there by the name of Search." Do we need further illustrations to demonstrate the truth of our assertion that society will turn a deaf ear to the best of leaders if they are too much "out of step" with the masses? Experimenters we must have if education is to continue to become more scientific but we must not overlook the important principle that society itself and not a few outstanding leaders finally determines its school. The leaders, such as Professor Dewey and others who saw ahead of their day and wrote on such helpful themes as "School is life," etc., made great contributions and we should give the educational philosopher his place. But our thesis implies that we are honoring the prophet in his own day because his ideal on which he fixed our attention as educators, lay just around the corner—near, but out of sight. Society is adjusting itself to many of Dewey's important points of view because these principles are so nearly in accord with the trend of our social evolution. Society did not appreciate Mulcaster because he was about three hundred years removed from a "present trend."

It seems that the important lesson that the present generation of educators can gain from the cases in the history of education that portray society as a "self-determiner" of what shall last, is that we should look with a considerable degree of distrust on any scheme or procedure that does not take into account "our evolving and evolved entities." What we need is not a brand new school but a revision and an amendment of the old school that we have evolved during the centuries of our existence.

Second, social evolution has decreed that in a democracy such as the United States the school shall be Public, free, and universal. As is generally known, the first school in our land was private and was supervised by the church chiefly in whose interest it was born and

nurtured. To us now, it seems a bit of accident that the New England selectmen who were in the main the elders of the Calvinist church, assigned the matter of schools to the townhall instead of the meeting-house assembly on the small plea that the (state) townhall was already handling money for roads and so on. But this germ thought of a church state that became the prototype of the political state system of schools because it showed society the best solution of its many problems emanating from the big problem of initiating and administering a democratic government, was accident only in the sense that truth was thus uncovered. As the democracy has thus evolved the necessity of a means for propagating democratic ideals has ever become more apparent. This thought explains why we must have schools throughout the states under the control of the public at large, therefore called "Public."

That these must be free was determined at great price. It was easy for the man from New England to see that the school should be free but this idea was by the Virginian long associated with charity and instead of the government arbitrarily determining the solution, the matter was in a large measure left to work itself out and the evolution has decreed that all state, tax-supported, public schools shall be free.

We are still in the process, probably, of evolving the decree that the public school shall be for a given period at least in the schoollife of every child of the nation compulsory. This does not mean that any leader or group is consciously endeavoring to dictate the school that shall or shall not offer tuition to the young American. But as time goes on it is as reasonable to expect all to see the real purpose of the public school in relation to government as it was to expect that the conscientious Virginian would ever endorse free schools. Nobody can say with certainty, of course, which way these problems will turn out but their solution is on the way. Three hundred years ago or one hundred years ago or even twenty-five years ago, no considerable number of persons in any state of the union, probably, would have been concerned with what schooling should be offered to all, or whether certain children got any schooling. The social concern (social conception) of school is rather modern and in the making. Somehow, we feel that education makes better citizens through making them less ignorant and less superstitious, and wanting better citizens for more or less selfish reasons, we believe that school should be compulsory. The question of what school shall the children attend is plainly secondary in its origin. If a person is anxious to have all children go to school he is likewise interested that the school shall be demanded to teach properly the essentials which every citizen should know in common with every other citizen of the country. This is the parallel argument for teaching a common language to promote mutual sympathy and understanding as a means of social solidarity. As a rule, attendance at any school, private or public, satisfies this requirement but in a few

instances, notably the case of the state of Oregon that passed a law placing all education under public control, there is evidence of a changing conception of the function of the public school such as to indicate a demand that all children should for a part of their schooling at least, attend public schools. The Oregon case while not in keeping with precedent as indicated by an adverse court decision is a good illustration of the way in which the social mind grows and attempts to express itself.

It may be that the best lesson for the educator to draw from what one may observe in this phase of our social determination, is to be willing to follow the truth. If it finally appears to mutual advantage to have all children attend a common school for a given period and to allow another period for the church or other agency to have its adherents, who shall say no? If this question is as important as it seems to be, the right answer will surely come.

Third, the dominant philosophy of education varies with changing social demands. This fact most of all is indubitably written in the pages of educational history. For a time education was generally conceived in terms of illiteracy only. In more recent years, we have defined education in terms of adjustment including social as well as physical or biological adjustment; in terms of growth or life; and in terms of changed response. The advantages of school according to the older conceptions of the aim or purpose of education centered in the individual whereas we tend to lay stress today upon the advantages to the group coming from having the individual properly educated. As an integral part of this conception we say that the state cannot afford not to have its citizenry educated and that education is a defensive measure of the government.

The status of our social conception of the school was very well stated in a public address by the president<sup>1</sup> of the National Education Association when he said, "The result (of what has taken place) has been the gradual transformation of the school from a place of mere training in the essentials of academic learning for the children of such parents as were rich enough to dispense with their labor, to great service stations, tax-supported, and buttressed by child labor and compulsory attendance laws in every state in the nation, dedicated to the service of all the children of all the people. A service program has therefore been built up that reflects the changes in our domestic, social, and economic life. There is not a subject in the program but has found its place there as a result of either mandatory or permissive legislation or of pressure on the school officers by organized, active, persistent local groups. Our present program, therefore, **is the people's own, worked out and adopted in response to their demands.** As it has been

<sup>1</sup>Frank D. Boynton, Education: What Program? What Price? Rep. N. E. A. Feb. 1929.

made, so it will be remade continuously . . . to meet the needs of a changing social order."

The school is here pictured as consciously responding to social demands or directions. Its relation to society is that of a child to a parent. While it respects the parent from which it sprang, it must in addition to carrying out the wishes of society be the protector of society's welfare. For example, society speaking through one of her children, the press,<sup>2</sup> has made her demands very explicit in statements like the following:

"What the business world wants today is character. Men and women are wanted who can be trusted, who will bear responsibility without wavering, and who keep faith in strictest honesty; upright men and women who have honor and who heed the voice of duty in the face of cynicism. **To produce such men and women is the duty of the public school.** Every child born in America is entitled to receive the highest education of which he is capable. It is the sole means by which progress is made, even that which has been made preserved. The country will never be secure in its republic until character training is given equal importance with intellectual training; until youth is taught not only facts but to know itself and to exercise self-control."

It is a challenging fact for the school that good citizens do not just happen to be so. If we want citizens who love our country and respect the laws, the school exists to train up our children in this way. Bad citizens are usually the neglected children grown up. The different attitudes of good versus bad citizens is due in a large measure to different teaching or other experiencing during the school age. Because the out-of-school experience is quite as potent as formal schooling, the task of making good citizens is doubly difficult. This is especially true when the children are reared in homes where one or both parents are of foreign extraction and have not been indoctrinated with American ideals. For example, is it any wonder that we have a growing disregard for law when such laws as the Volstead Act are in such direct conflict with the ideals brought from European shores by the parents of many of our children. Not only do such parents fail to see the necessity of obedience to laws that prohibit what they were always allowed in "the old country" but they create thereby an environment for their children that unconsciously engenders a similar disrespect for law. In many cases, the state supervised school that exists to develop the American ideal and sentiment, does not come in contact with many children that most need such instruction.

In his inaugural address, President Hoover has called attention to the necessity of all educative agencies trying to increase respect for law and for regularly constituted government. In part, he said:

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<sup>2</sup>A recent quotation from the Lexington (Ky.) Leader.

"Crime is increasing. Confidence is rigid and speedy justice is decreasing. . . . To consider these evils, to find their remedy, is the most sore necessity of our times." Consider the likelihood that young people who have once taken up a life that is inimical to society will never be restored to good citizenship, all school—public and private—must look seriously upon this grave problem of training for righteousness in civic life. According to figures quoted from Mabel Walker Willebrand in the press, recently, "more than 400,000 men, women, and children leave the jails, penitentiaries, and reformatories throughout the nation every year . . . and many of these leave these places of confinement more embittered towards society, more a menace to their fellowmen than when they entered jail doors or prison gates." How important it is to have the school an institution dedicated to the task of directing unspoiled future citizens aright. We must direct them while they are young, if ever. Society is gradually passing this important work into the hands of the school. The school exists to serve society and must graciously accept this or any other task not done as well by some other agency.

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<sup>3</sup>"Schoolhouses of Crime," Pittsburgh Post, Apr. 14, 1929.

THE ORIGIN OF MENTAL TESTS<sup>1</sup>

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## Introduction.

No science can attain the state of certainty and exactness except by the route of experimentation and measurement. Each and every one of the physical sciences gradually evolve through that method. It can justly be said that undoubtedly the experimental method in Germany forms the real foundation, or at least a good deal of the soil in which the mental testing movement germinated. The field of psychology had its roots, one might say, back in the time of the Greeks, but mental testing as a phase of it, in the present sense of the word, is very recent. If we are justified in calling psychology a science, and many believe that we are, it is probably due to the results of the experimenting of the last three or four decades.

Although Wilhelm Wundt cannot be credited with initiating the mental testing movement and showed no sympathy with the problem of individual differences, we must recognize the fact that several men who came under his teaching did play important parts in the development of tests. The chief contribution which he made in this connection was in his emphasis on the experimental method and attitude.

"There have been four methods of attacking the psychological data. All of these, following the lead of the older sciences, attempt to be quantitative. All have been concerned with measurement, but measurement of different sorts."<sup>2</sup> Briefly stated they are as follows:

1. The psycho-physical method. Weber (1795-1878) discovered that the report of the individuals on differences in sensations did not agree with differences in the stimulus scale of intensity. We owe to Fechner the debt of having determined more accurately the mathematical features of Weber's work.

2. The study of different limens. The prominent names here are G. E. Muller and Urban.

3. Mental measurement, which is practically synonymous with mental testing as now used. This method is an outgrowth of the reaction time studies and found its first application to higher mental processes in the statistical studies of Francis Galton.

<sup>1</sup>This paper deals principally with the origin of intelligence testing and for that reason does not cover any of the latest developments. It is not the writer's intention to review all the literature on mental testing but rather to restrict the material to the early beginnings in England, France, and America. The Introduction gives credit to the Wundtian influence in connection with the experimental psychology of Germany. However, the main portion of the paper deals with those who really began the mental testing movement, namely: Binet, Galton, and Cattell.

<sup>2</sup>Young, K., *The History of Mental Testing*, Ped. Sem. v. 31, p. 3.

4. The physiological method. Here the unit is expressed in terms of the stimulus, for instance, as among rigid behaviorists.

It is the third method with which we will concern ourselves here. The outstanding names in connection with the mental testing movement are Galton, Binet, and Cattell. The remainder of the material presented here will deal with the movement as it developed in England, France and America, taking the above named men as the main protagonists.

#### The English Contribution: Galton and Others.

In the person of Francis Galton (1832-1911) we find a man who was very active in several branches of scientific research. His work in connection with mental measurement grew out of his anthropometric studies. He began his study of heredity as early as 1860 and in 1869 published his "Hereditary Genius." He continued his studies of eminent men in his "English Men of Science," published in 1874. Later he took up the investigation of the nature of mental powers and in order to get material devised the questionnaire method. He used this method especially in the study of mental imagery in which his researches, published in 1883 in "Inquiries Into Human Faculty," are classic.

In connection with these various studies he developed the statistical method to get results of an objective nature. In fact he was probably first to conceive of the idea of applying the method of Quetelet to the treatment of the results of experimental studies of associative processes.<sup>3</sup> It was his experimental approach to the study of physical traits in men carried on to the mental traits, however, which gave rise to his new investigations with mental reactions.

With him the main interest was with quantitative measurement of anthropological and psychological traits. As a result of that interest we find that he established, during the eighties, an anthropometric laboratory at the South Kensington Museum in London. Here, for a small fee, one might have his various capacities, physical and mental, measured.

Galton has been called by Professor Boring "the father (in large part) of mental measurement, of individual differences with respect to traits, with Fechner and Charcot of ideational types, the originator of the questionnaire and of the theory of eugenics."<sup>4</sup>

Associated with Galton in the English movement was Karl Pearson who also carried on a number of statistical investigations which have made him known throughout the world for his contributions of a statistical nature to eugenics, anthropology, and psychology. In addition we will mention in passing, for we do not have room here to discuss them, the names of Cyril Burt, Carl Spearman, Boring and Yule.

<sup>3</sup>Young, K., The History of Mental Testing, Ped. Sem. 31, 1-48.

<sup>4</sup>Young, K., The History of Mental Testing, Ped. Sem. 31, 1-48.

The English contribution to mental testing has been largely one of the refinement of statistical methods of treating test data. We shall want to refer later to how this influence reinforced the French scales and tests. In the second place the works of Pearson, Burt and others lend support from the statistical side to the thesis of Galton that mental ability is inheritable in terms of known laws of heredity.

#### The French Contributions: Binet and Others.

The commission which was appointed by the Minister of Public Instruction of France in 1904 was charged with the study of measures to be taken for insuring the benefits of instruction to defective children. The members of the commission decided that no child suspected of retardation should be eliminated from the regular classes and put into special classes until he was subjected to a medical and pedagogical examination.

But how these examinations were to be made, what methods were to be used, what tests devised, and so on, were directed by Alfred Binet and Th. Simon. "In order to recognize the inferior states of intelligence, we believe," said Binet, "that three different methods should be employed. We have arrived at this synthetic view only after many years of research, but we are now certain that each of these methods render some service."<sup>5</sup> These methods are:

1. The medical method, which aims to appreciate the anatomical, physiological and pathological signs of inferior intelligence.
2. The pedagogical method, which aims to judge of the intelligence according to the sum of acquired knowledge.
3. The psychological method, which makes direct observations and measurements of the degree of intelligence.

The work of Alfred Binet (1857-1911) in devising his scale for mental testing was a very original piece of work. However, his training and the forces of circumstances directed him toward this work. That, together with his inventiveness, subtlety and facileness brought about this wonderful instrument which has become so well-known in every country. Nor should we ignore the influences which Binet's predecessors and contemporaries had on him.

Binet first studied law, then medicine, but after some time in the biological laboratory of Balbiam, he became concerned with experimental psychology. In 1889 he founded the first psychological laboratory in France at the Sorbonne. His life was permeated with the influences of biology, medicine and psychology. In fact his father was a physician in the south of France. From his father he must have accumulated much of the medical lore of his day, with its place for psychotherapy, suggestion and hypnotism. The work of E. Seguin (1812-1880)

<sup>5</sup>Binet, A., *The Development of Intelligence in Children*, Vineland, N. J., 1916.

with idiots probably drew Binet's attention to work along the line of the psychology of the abnormal.

Brett has stated Binet's position, insofar as his contributions to technical psychology are concerned, very well in the following extract:<sup>6</sup>

"In Germany experimental work had tended to remain an appendage to physiology, an affair of nerves and reactions. Binet has the credit of moving on to comparatively new ground and attacking the intellectual life as a whole by experimental methods. The traditions which mark the different stages of Binet's career have an obvious logical sequence. Interested from the first in psychological phenomena as they are to be found in daily life, Binet carries the methodical principles of the laboratory into the street and the school. He constructs a bridge from the place of instruments and isolation to the complex world of characters. His range was thus extended from his earliest studies on micro-organisms to the beginning in 1895 of Individual Psychology, which was then a new department. A more determined movement toward the understanding of minds as unities was then set on foot. The results were intended to be practically useful and were quickly developed in the sphere of pedagogy and legal testimony."

From 1904, when he was appointed to devise methods of segregating children in the public schools for more effective pedagogical purposes, until 1911, the time of his death, Binet spent his energies in developing this new method of intelligence which we call the "mental test" scale.

Binet and Simon published their first results of the tests in 1905. After considerable refinement, which was necessary because the early years seemed too easy and the later years too hard, a revised series appeared in 1908. The 1908 series comprises fifty-six single tests, a group of which is assigned to each age from three to twelve. A certain minimum of performance in every test constitutes a "pass;" and the subject is graded on the basis of number of tests passed as having a degree of intelligence normal to such-and-such a year. In 1911 a second revision of the tests came out. In terms of mental age Binet endeavored to express the real qualitative differences between pupils.

Binet and his associates, then, are typical of the French attitude in general. There was a close intimacy between medicine and psychology. In fact some have termed the French psychology "Medical Psychology." It seems, then, that so far as Binet's work itself is concerned we may sum up his contributions as follows:

1. His notion of a study of the individual's higher capacities rather than the atomistic study of sensation as in German psychophysics

2. His conception of a scale, a battery of tests arranged and graded according to the average for various chronological levels.

<sup>6</sup>Brett, G. S.. *The History of Psychology*, Geo. Allen & Co., London, 1912.

## 3. The idea of mental age.

**American Contributions: Cattell and Others.**

In America the mental testing movement has grown out of the study of individual differences. Foremost in this line of study has been James McKeen Cattell 1860- . . . ). Psychology has taken several trends in this country, but the trend which has been most conducive to the development of the mental testing movement is that under the leadership of Cattell and other Columbia men, principal of whom are Robert Woodworth and E. L. Thorndike. They have been dealing with individual differences by the statistical method and have been interested primarily in the application of psychology to education, industry and the social world generally.

Cattell in 1886-87, on his way home from Wundt's laboratory, visited Galton at South Kensington Museum, where the latter had set up apparatus and devised methods for giving various physical and mental tests. No doubt, he was stimulated by this visit, and when he returned to this country he took up, first at Pennsylvania and later at Columbia, extensive researches into individual differences. The first results of these were published in 1896. But in 1890 he had published his notable paper "Mental Tests and Measurements" to which Galton appended a footnote. So we find that by 1900, and even before, considerable work had been done with mental measurement in England and the United States. Thus everything was in readiness in this country for the introduction of the testscale idea as worked out by Binet.

Cattell in an address before the American Association for the Advancement of Science, in which he surveys the progress of psychology and measurement of individual differences, states very clearly the origin of the measurement of individual differences and the extent to which psychology is becoming practical and influential in society. He has presented it so well that a few extracts from his address will be included here:

"Those experiments, published in 1885, were the first measurements of individual differences in psychology and in connection with them the term individual difference was apparently used for the first time. The term mental tests, which also has become an international word, was used by me a little later—we owe its earliest scientific development to Francis Galton, who was Darwin's cousin.

The most important work for psychology and its most useful applications are the measurements of individual, group and racial differences, and the determination of the extent to which these depend on native endowment and on subsequent experience."<sup>7</sup>

In the latter part of Cattell's address (which is found in the Janu-

<sup>7</sup>Cattell, J. McK., Some Psychological Experiments, *Science*, January 1 and 8, 1926.

ary 1926 issue of Science), as noted in the footnote, Cattell makes the observation that—

"The Binet-Simon scale first used in 1905 to diagnose subnormal children and in 1908 to measure the mental age of children, developed in this country by Dr. Goddard, Professor Yerkes, Professor Terman and many others, together with the group tests that we owe to Mr. Rice, Dr. Courtis, Professor Thorndike and many others, have been of untold value to our schools and to the children who are the ultimate origin and end of all our efforts. Even more important than the segregation of backward children is the giving of opportunity to children of promise and of genius, which should perhaps be the principal concern of a democracy."

As was stated above, the Binet tests were first introduced into this country by H. H. Goddard. In 1908, during a trip abroad, Goddard came in contact with DeCroly who told him of Binet and gave him a copy of the Binet tests of 1905. Goddard experimented with the tests at the Vineland Training School in New Jersey. In 1910 he began publishing results of his findings with the tests on children at the Vineland School. Another important step in connection with Binet's tests consisted of the work done by L. M. Terman in the famous Stanford-revision which was a refined and, in addition, an introduction of the "Intelligence Quotient" which made mental testing more quantitative rather than qualitative.

In summing up the main contributions of Cattell and others in America in originating the testing movement we should note the following trends:

1. The large contributions of Cattell in the elaboration of statistical procedure and in the application and evaluation of tests.
2. The work of Binet introduced by Goddard for clinical purposes.
3. The refinement of Binet's tests and their introduction into the classroom; also the notion of the intelligence quotient.

#### Summary.

Galton, and soon afterwards Cattell, and still later Binet, began working at the study of traits and reaction times. It was this new approach to the study of human nature through the study of traits and by examining the individual reactions to certain tests and problems that was to result in the movement for mental measurements.

England and America have concerned themselves with expressing their findings in statistical terms such as: Averages, measures of dispersion and correlations. In France the testing grew out of clinical experimentation. In each case real advance seemed to result from some practical need.

It was the American psychologists, however, who brought the Binet idea of a scale and the statistical method of treating test data

together. They have refined the statistical treatment of tests, have extended their application and have brought the mental tests into common usage.

**Bibliography.**

1. Binet, Alfred and Simon, Th., *The Development of Intelligence in Children*, Williams & Wilkins Company, Baltimore, 1916.
2. Brett, G. S., *The History of Psychology*, Geo. Allen & Company, London, 1912.
3. Cattell, J. McKeen, *Mental Tests and Measurements*, *Mind*, 15: 373-380 (1890).
4. Cattell, J. McKeen, *Some Psychological Experiments*, *Science*, Jan. 1 and 8, 1926.
5. Galton, Francis, *Inquiries into Human Faculty and Its Development*, E. P. Dutton & Company, London, 1908.
6. *New International Encyclopedia*, *The Mental Tests*, Dodd, Mead & Company, New York, 1916.
7. Pintner, Rudolph, *Intelligence Testing*, Henry Holt & Company, New York, 1923.
8. Wylie, A. T., *A Brief History of Mental Tests*, *Teachers College Record*, 23:19-33, January, 1922.
9. Young, K., *The History of Mental Testing*, *The Pedagogical Seminary*, 31:1-48, March, 1924.

SOME ECONOMIC ASPECTS OF SOUTHERN  
RECONSTRUCTION\*

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The extent to which Northern capital helped in building up the South just after the Civil War has always been a matter of uncertainty. Most statements concerning it have been based merely on probabilities, and have been made without thorough investigation. If this point could be cleared up, a valuable light would be thrown on Reconstruction and the later economic history of the South.

The South had to have money for its Reconstruction. Railroads, farms, factories, schools, bridges, public buildings, and private homes had been laid waste. The South could not herself provide the money for rebuilding these essentials. Every dollar of available capital had been wiped out by the emancipation of the slaves and the repudiation of the Confederate debt. And yet there was considerable activity in all lines of construction almost immediately after Appomatox. Where, then, did the money come from?

There are two possibilities — Europe and the Northern states. Europe is almost immediately eliminated from consideration. Southern credit was bad across the Atlantic. Mississippi had repudiated a bond issue in 1842, and brokers in London and Amsterdam had been heavy losers. Soon after that Adams, in the House, commented on this situation, and a commission that tried to float an issue in Europe failed dismally. After the war some losses were again sustained in the repudiation of the Confederate debt. European investors can hardly be blamed if they looked askance at the disordered South and with commendable shrewdness hid their spare money in superannuated socks. Furthermore, after the Emancipation Proclamation European sentiment had been with the North anyhow. All in all, it is very unlikely that large amounts of European money flowed into the South.

But what about Northern money? It has generally been supposed that Northerners did not invest in the prostrate South because of the political uncertainty prevailing there and because of the superabundant opportunities for investment elsewhere in the United States. The West was booming; manufacturing was booming; gold, silver, wheat, oil, railroads and a myriad of other enterprises cried out "Let us make you rich—quickly, certainly and easily." Dunning says that because of this the Northerner did not invest in the South, and so say other authorities.

But the South got money. If it didn't come from the North, where

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\*Owing to the nature of this paper and the limited space, it has been impossible to make use of foot-notes for reference. The chief sources of information are the Commercial & Financial Chronicle and the standard monographs on Reconstruction. M. S.

did it come from? The answer is—it had to come from the North, and did. The political uncertainty in the South had an economic significance only for the white, disfranchised Southern taxpayer. The Federal soldier, the carpet-bagger, the Union League, the Freedman's Bureau, all served to remove any uncertainty from the minds of Northern investors. Their money was bound to be protected. There were abundant opportunities to reap a golden harvest, honestly as well as dishonestly. These opportunities were not overlooked.

But all this, like Moliere's fencing-master, is "killing a man with demonstrative logic." The evidence is more conclusive than the reasoning, and this I will now examine. In this discussion, for the purpose of convenience, I will use Reconstruction as a term to cover the whole fifteen years from 1865 to 1880, and by Northern state I will mean, of course, any state not actually in the Confederacy.

The first question is: Who bought the state and municipal bonds floated by the South during Reconstruction? The answer is easy to find. In North Carolina one Swepson, a native swindler, cooperated with Henry Clews, the New York banker, a Mr. Littlefield from Maine, and other Northerners, in engineering his schemes and floating the huge issues. When a proposal was made in the legislature to pay interest on these bonds in cash, it was opposed by a few members on the grounds that the only ones to profit would be "Yankees." When North Carolina repudiated these bonds the protest came from New York. No other evidence is needed. In South Carolina the situation was the same. The state's financial agent was H. H. Kimpton of New York. A large holder of her bonds was Morton, Bliss and Company of New York. Henry Clews, mentioned above, was active also in Georgia, and lost \$2,500,000 in the repudiation of one issue alone. The other Northern firms that held Georgia bonds were: Broadway National Bank, Metropolitan Savings Bank, Brooklyn Trust Company, Russell Sage, Union Trust Company, Ezra A. Boody, Richard Irvin and Company, Commercial Warehouse Company, Jas. B. Johnston and Company, S. W. Millbank, Hallgarten and Company, Fulton Bank of Brooklyn, Walter S. Johnson as receiver for the Maine National Bank, Morris K. Jesup, James R. Jesup, Drexel, Morgan and Company, Foster and Thompson, L. Van Hoffman and Company, C. F. Timson and Company, Herman R. LeRoy, Samuel Raynor and Company, and the New York Warehouse and Security Company. Georgia's financial agent was the Fourth National Bank of New York, and Governor Bullock's semi-official agent was H. I. Kimball and Company of New York.

In Florida we get about the first evidence of bonds being sold in Europe. Of a \$4,000,000 issue, floated to aid a fraudulent railroad company, a large part was sold in Holland through S. W. Hopkins and Company of New York. The railroad, by the way, fell into the hands of our friend Littlefield, mentioned above in connection with North

Carolina. The rest of Florida's bonds were sold in the North, some of the holders being Jay Cook and Company, First National Bank of New York, New York Warehouse and Security Company, Soutter and Company, and S. W. Hopkins and Company.

There is no need to take the other states in detail. They are all the same except that once again, in the case of Alabama, there is some evidence of selling bonds in Europe. Practically all the Southern states had financial agents in New York. When the governor of Alabama wanted to investigate a bond issue he had to go to New York. When the governor of Tennessee had controversy over bond settlements he dealt only with a committee of New York holders. Some of the Northern firms not yet mentioned, that dabbled in southern securities are: Winslow, Lanier and Company; New York Guarantee and Indemnity Company; Duncan, Sherman and Company; Drexel and Company, Philadelphia; Williams and Guion; American National Exchange Bank; the Stantons of Boston, etc. Of those already named who also had enterprises in the remaining states, the following ought to be noted: Henry Clews and Company, and Soutter and Company. The following Northern firms, not yet mentioned, advertised regularly that they made a specialty of southern securities: J. M. Weith and Company; Lancaster, Brown and Company; W. N. Worthington; Levy and Borg; Osborn and Cammack; and Conover, Vincent and Company. When Louisiana repudiated her bonds, the protest came from New Hampshire and New York. Securities, not only of southern states, but also of towns, counties, school districts, etc., were regularly quoted on the market and advertised in financial papers throughout the North. There seems little room for doubt that the great bulk of these bonds were bought and held by Northern financial interests. This, in fact, is specifically given as one of the reasons for wholesale repudiation by the Southern states.

So much for public securities. Turn now to the railroads. On August 10, 1867, the Commercial and Financial Chronicle carried a long editorial on the progress of railroad building in the South. It commented on the great activity, noted that five thousand miles of line were under construction, and then said that Northern money was available for and participating in these enterprises. The Chesapeake and Ohio is a good example. Virginia was going to build this road with capital raised exclusively within her own limits. By November 1868 Chesapeake and Ohio bonds were on sale in New York at the office of Dean, McGuinness and Company. In November 1869 the completion of the road had to be turned over to New York capitalists, prominent among whom was the firm of Fisk and Hatch. By 1870 the road had passed into Northern control, for in the election of directors in December of that year seven of the eleven chosen were Northern men.

Cases like this can be multiplied indefinitely. In 1866 a Pennsyl-

vania company took over the Coosa and Tennessee Railroad. In the same year a New Yorker, Marshall O. Roberts, bought the Florida Railroad. In 1868 a Virginia Road, the Holliday's Cove, passed into a Northern merger, and the Mississippi Central was turned over to a Delaware firm. A new road from Mobile to New Orleans, completed in 1869, was built with Northern money exclusively. The East Tennessee and Virginia and the East Tennessee and Georgia were consolidated under Thomas H. Callaway of New York. The Little Rock and Fort Smith had its financial offices in Boston. In North Carolina the Wilmington and Manchester Railroad was partly owned by Morris K. Jesup of New York. The bonds of the Vicksburg and Meridian were held by Northerners. The treasurer of the Shenandoah Valley was a Philadelphia man. The bonds of the Central of Georgia were held in the North. The Macon and Western had Northern firms represented on its board of directors. The Macon and Brunswick got under Northern control after 1870. The Brunswick and Albany was a New York road. The Western and Atlantic was leased to a company at whose head was W. B. Dinsmore of New York, who was also president of the Southern Express Company. The Memphis, El Paso and Pacific had its offices at 66 Exchange Place, New York. R. C. Link and Company of Philadelphia made a stock subscription of \$7,000,000 to the Norfolk and Western. J. E. Tainter of New York bought part of the Little Rock in 1869. *Et cetera ad infinitum.*

Furthermore, the securities of Southern railroads were always quoted and advertised for sale in the Northern markets. The following firms are among those who dealt in these commodities: Soutter and Company (once again!); Drexel, Winthrop and Company; Henry Clews and Company (always!); Morris K. Jesup (another regular); Winslow, Lanier and Company; Condict, Jennings and Company; Drake Brothers; Bayne and Company; J. B. Alexander and Company; John J. Cisco and Company; J. M. Weith and Company; et al. All these, of course, are Northern firms. In checking over the financial papers of that period I have found the securities of no less than fifty-five Southern roads advertised in Northern offices.

There is no need to go further. There is no time left to go into other enterprises such as banks, factories and plantations, but it's all the same. A very deluge of money flowed across the line from the victorious states. The papers of the time describe this influx as "prodigious" and "ever-increasing." One interesting feature, however, sometimes in the nature of an exception, must be noted. In 1865 and 1866 the shrewd Yankee investors saw a great opportunity to exploit southern cotton plantations. Immigration and planting companies were organized with speed and enthusiasm; land was bought, equipment installed and money lent to independent planters. By 1868 there was hardly a dollar of Northern money in the southern planting game! The

whole movement was a failure because the Northerner could not use negro labor. He was up against a force, or rather an inertia, that he didn't understand and couldn't handle.

These are the facts. The next question is—"What about it?" Here I can suggest only a few results of this situation. The South was almost literally bought out, became in a sense a mere lessee or tenant of resources which were formerly her own, and the ramifications of this fact are too extensive to be taken up in detail. In the first place this added materially to the night-mare of carpet-bag Reconstruction. Much of the money that came South at this time came for no good reason. Southerners were exploited when they were helpless to defend themselves, and they have ever since keenly resented it. This was one of the reasons for repudiation. Furthermore, the profits from Southern resources have not stayed at home. This has been an important factor in the South's prolonged poverty and slow recovery. It has also been a contributing cause of her political solidarity. And one more point—the presence of Northern money in the South has gained for the South the friendship of Northern money-centers. This friendship has been of doubtful value to the South, and has sometimes been manifest only by profession, but it has endured, even up to last November 6.

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